FINAL REPORT

CONTRACT NO. NAS8-20271

TEST AND EVALUATION OF ARTICULATING JAW ASSEMBLIES

COLUMBUS DIVISION

NORTH AMERICAN AVIATION, INC.

COLUMBUS DIVISION

MANUFACTURING SERVICES

FINAL REPORT

TEST AND EVALUATION OF ARTICULATING JAW ASSEMBLIES

FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEORGE C. MARSHALL SPACE FLIGHT CENTER

CONTRACT NO. NAS 8-20271

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ABSTRACT

This report covers the assembly, installation, and testing of a set of NASA owned articulating jaw assemblies on a Hufford A-60 Stretch Forming Press at the Columbus Division of North American Aviation, Inc. Performance of the jaw assemblies was compared to the jaws normally installed on the press. No significant differences were found between the two sets of jaws. Some recommendations concerning future jaw and stretch press designs have been included.

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I - INTRODUCTION

A. BACKGROUND

Currently active rocket, missile, and space programs have generated new and unusual requirements for materials and fabrication techniques. Stretch wrap forming has proven to be a useful process for forming large contoured sheet metal sections. The effective capacity of existing stretch wrap forming presses has been limited, in many cases, by the design and holding power of the jaws rather than available forming pressures. Some existing jaws and jaw mounting systems have also limited the complexity of the parts formed by this method.

The National Aeronautics and Space Administration, through George C. Marshall Space Flight Center sponsored the design and fabrication of a new set of jaws (Contract No. NAS8-11707) to fit the Model 60 Hufford Stretch Forming Press. The new jaws include features, which it is hoped, will increase both effective forming ability and forming pressures of existing presses.

B. PROGRAM OBJECTIVES

1. To assemble, install, and test the NASA furnished articulating jaws on the Model 60 Hufford Stretch Form Press, testing performance parameters of the jaw assemblies prior to test forming.
2. To install a customer furnished form die on the Hufford Press for the purpose of forming test parts from customer furnished material.
3. To form a series of four (4) test parts using the customer furnished jaws and material.

4. To form a series of two (2) test parts on the same die using the jaws presently installed on the press and customer furnished material.
5. To develop and report data comparing the two (2) sets of jaws with regard to gripping and pulling strength, jaw movements, ability to form material to the form die, springback after relaxation, and effects on material being formed.
6. To develop and report information to assist in studies to determine the need for larger stretch presses and possible uses for larger presses.

II - CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. There were no major differences in the performance of the two sets of jaws during the tests conducted under this contract. Elongations, reductions in thickness, and strain data are comparable for both sets of jaws, although strain distribution across the ends of test blanks was more uniform with the NAA jaws.

2. The NAA and NASA jaws are very similar in jaw segment and gripper design, and the method of contouring the jaws. The NAA jaw segments are only 6" wide compared to approximately 11" for the NASA jaws. The small width segment provides a more flexible jaw assembly for difficult shapes or sharp contours and more evenly distributes the stretching force across the end of the work piece. When contouring with the wider segments, higher stresses are concentrated in a smaller area, which can cause cracking of the work piece

3. The NASA jaws have two features which are not available on the NAA jaws; individual in and out movement of the jaw segments in the plane and direction of pull, and a swivel arrangement which allows each jaw to be self aligning, seeking its own centroid when pulling.

4. Good forming results were obtained with both sets of jaws, with the degree of forming generally proportional to test blank loading. Forming of the 1/4" 2219-T37 (all NASA part numbers) blanks was limited by jaw and blank width, while forming of the heavier 3/8" 7075-T6 blanks (all NAA part numbers) was limited by press capacity.

5. Stretch forming of large structural gore sections for large diameter bulkheads is feasible if facilities of sufficient size and power were available. Larger stretch forming equipment would also allow application of the stretch forming technique to other areas of large booster fabrication, such as skin and adapter sections.

6. The advent of new aircraft designs such as the C5A and SST appear to present another favorable area for the use of large stretch formed skin sections. Larger skin sections require fewer joints, resulting in vital weight savings. Larger skin sections would also allow wider application of new structural bonding techniques or the bonding-fastener combination used on some present aircraft.

B. RECOMMENDATIONS

1. Stretch wrap forming should be considered for larger sections than presently done, and for shapes now formed by other methods. This would require the design and construction of larger presses than the present 350 ton maximum.

2. Present stretch press design concepts should be extended, incorporating new control systems and improved jaw designs.

3. When a larger stretch forming press is built, it should be installed in an experienced facility, where operating, tooling, and engineering personnel are thoroughly acquainted with present equipment and techniques. For the most efficient utilization of such a machine in the shortest time, its installation and start up should be carried out through a series of orderly, well planned development programs.

III - DISCUSSION

A. JAW ASSEMBLY and INSTALLATION

When the jaws were received, it was obvious that the detail parts had never been assembled. Some of the parts appeared to be unfinished; for example, of four identical pins, one had been heat treated and three had not. In general, it was necessary to rework all holes, threads, and part to part fits. Specific items requiring corrective action are listed as follows:

1. Hand lap 2 collars, 199-C1008, to 2 segments, 199-J-1002-2.
2. Hand lap 2 collars, 199-C1008, to 2 segments, 199-J1002-1. All four collars lapped in for free easy turning.
3. Adjust 4 nuts, 199-C1009, to 4 collars, 199-C1008 using 8 spacers, 199-C1007, and set a clearance of .002"; drilled, tapped, and set as print called for.
4. Hand lap 4 large pin screws, 199-C1016, through holes in 2 segments, 199-J1002-2, 2 segments, 199-J1002-1, and 2 large center segments. All holes must be in alignment for large pin screw to pass through and screw into fixed collar and nut for adjustment of side segments to jaws.
5. All 8 large pistons and all 12 small pistons had to be lapped and fitted into proper position in each segment.
6. All 32 tapped holes in large center segment were not tapped deep enough to take special screws furnished. Attempts were made to tap deeper, but without success. After breaking several taps, shorter screws were installed with Loc-Tite.

7. All ball joints on all piston rods had to be reworked for fit and alignment with collars.

8. The 8 adjusting screws, 199-C1011, with ball seat in end, would not fit ball ends on part 87-1026, and had to be reworked in the machine shop.

9. Five of 12 holes drilled to mount piston retainers had been drilled too deep and hit oil ports. The holes had been partially filled with Plastic Seal, partially blocking out oil inlet ports. Oil ports were cleaned to allow proper piston action.

10. After complete assembly of one set of jaws, it was found that parts as made, did not allow enough clearance under screw head. This was opened up to .005" from .002".

11. Interlocking members of side and center segments were not machined flat, straight, or parallel. Grinding was necessary to get proper fits and clearances for assembly.

12. All 16 retainers, 199-C1006, that hold ball end of piston rod, 199-C1003, in center segment, had to be blued in, scraped and lapped for proper fit.

13. All 32 1/4" holes in center segment had to be retapped, but still impossible to use long set screws furnished to hold retainers and ball end of piston rod. Shorter screws and Loc-Tite were used.

14. All threads for hydraulic fittings (12) required retapping. Hydraulic fittings would only go in two threads deep, not considered safe or dependable for high pressure operation.

15. Eight new brass bushings were required for tilting mechanism. Bore of furnished bushings was .021" larger than the pins they were supposed to hold.

16. Four large bushings were required to adapt tilting forks to main pins on the press frame.

17. Eight lock nuts were made to center and hold tilting forks in main frame.

18. Special set screws were required for locking four large bushings in tilt frame.

19. Two special set screws were required to go through large bushings into main pin to establish and indicate perpendicularly centered position of tilt frame.

20. Drill and tap four 3/8" holes through tilt frame.

21. Drill and tap two 1/2" holes through tilt frame and large bushing.

22. Since the NASA tilt fork is designed so that lateral difference between main pivot pin and tilt piston pins is 6" less than NAA tilt fork, it was necessary to machine four new rods for tilt cylinders to compensate and make it possible to use the NASA jaws.

Installation of the jaws on the Model 60 Hufford Stretch Press is shown in Figure No. 1.

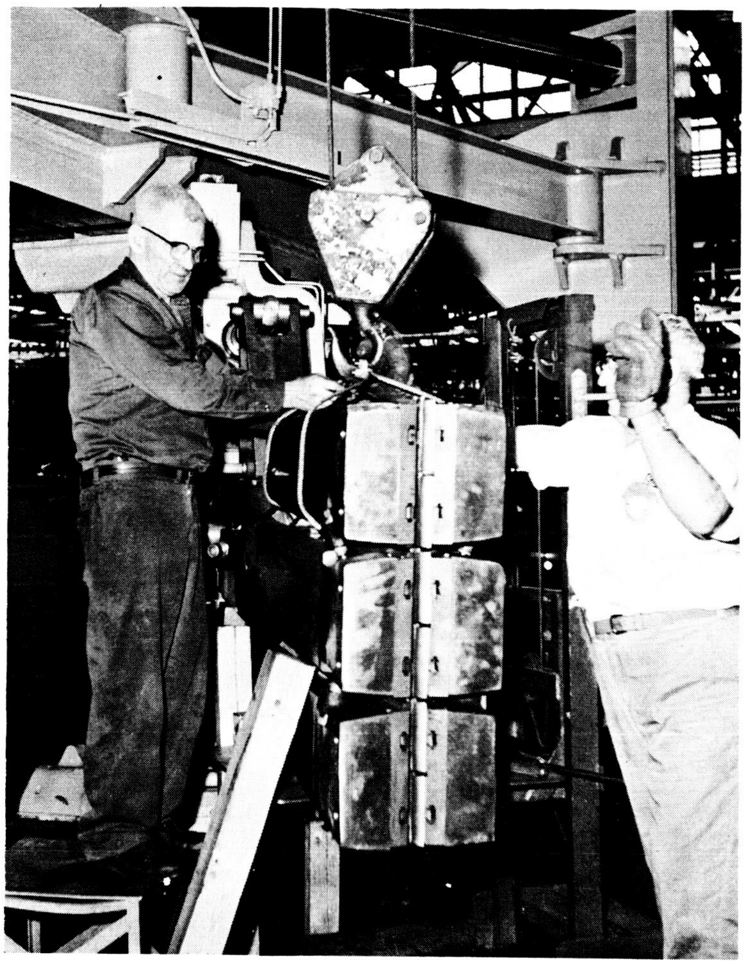


Figure No. 1 - Installation of NASA Furnished Jaws

Assembly and installation of the jaws were accomplished with one partial assembly drawing and a parts packing list from the jaw fabricator. No assistance was available from the jaw manufacturer. In spite of all these difficulties, the jaws were assembled, installed, and tested. All functions of the jaws were made operable with the exception of separate powered movement of the jaw segments in the stretch direction. This would require separate hydraulic and control systems, and for full utilization, special blank development.

This feature could be useful when forming difficult compound contours, if taken into consideration during part and blank design.

In Figure No. 2, the left jaw assembly is shown gripping an instrumented test blank. Several of the details of construction of the jaws may be seen in this photograph.

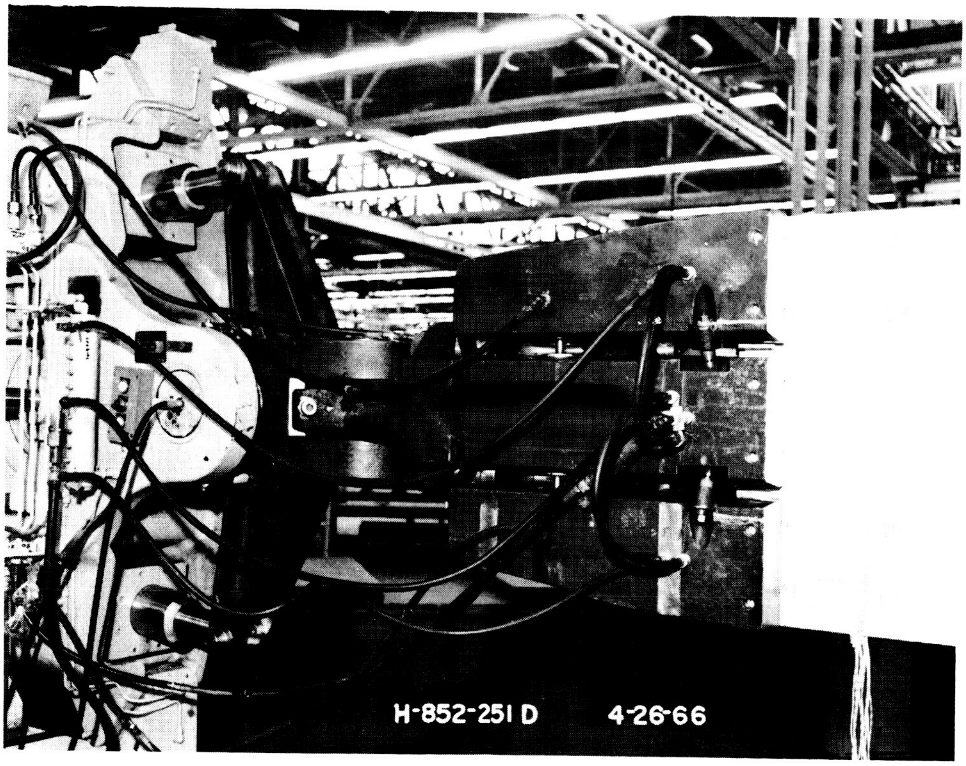


Figure No. 2 - NASA Furnished
Jaws in Operation

B. NASA FURNISHED FORM DIE

A compound contour form die was furnished by NASA for use on this program. The die was a tank bulkhead gore section, designed and constructed under NASA Contract NAS 8-11900. This die was used for all press check out and part forming tests. Die contour measurements were made before and after each stretching operation, using a Stockton Profile Gage (Figure 3) having an overall length of 48" and .020" thick laminations.

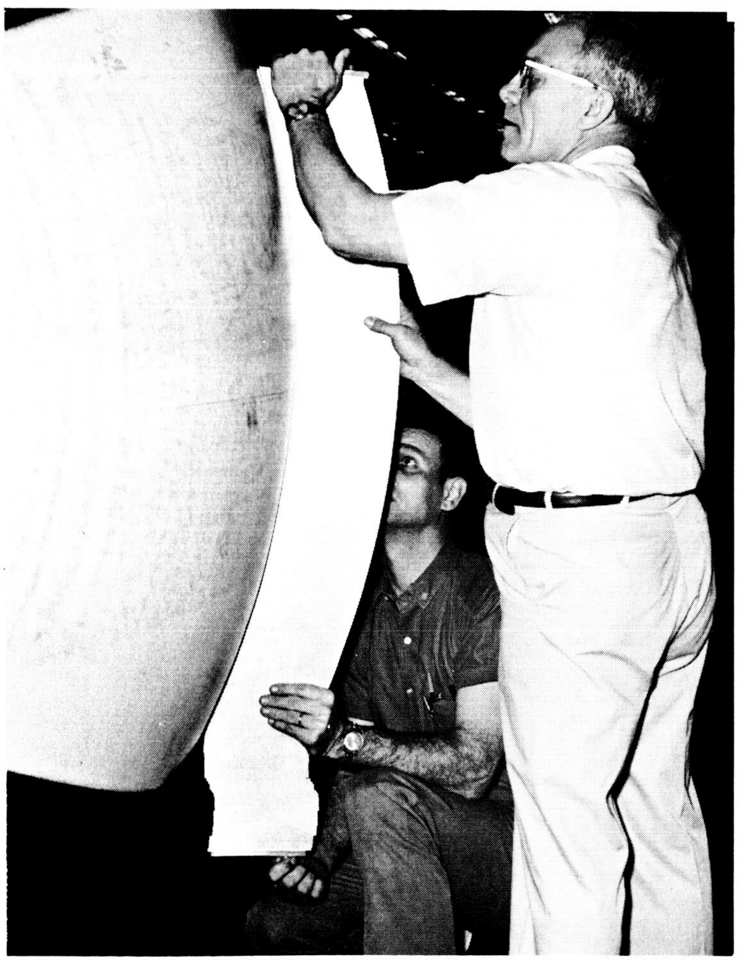


Figure No. 3 - Measurement of Die Contour With Laminated Profile Gage

No die movement or distortion was noted during the entire program. Installation of the die on the NAA press required only a simple, steel adapter plate for mounting bolt locations. During the program, the die was removed from the press and reinstalled several times with no difficulty.

C. PRESS CHECKOUT

Heavy aluminum alloy plates (3/8" thick, 7075-T6) were purchased for the press checkout tests. This alloy and thickness were chosen to safely withstand the maximum available press force.

Good tests were obtained with the NAA jaws (Table I). The NAA jaws are the Hydra-Curve model manufactured by Hufford with eleven (11) narrow segments. No gripping capacity tests were run for the NASA jaws because the NASA jaws which were designed for 1/4" thick material would not securely grip the 3/8" thick test plate. One plate was gripped as much as possible and the jaws were contoured to check this function. The wide segments of the NASA jaws caused high localized stresses between the segments which cracked the test plate (Figure No. 4).

Jaw motions and limitations for both sets of jaws are tabulated in Table II.

TABLE I

JAW CAPACITY TESTS

		NAA JAWS	NASA JAWS
Maximum Gripping Capacity or Pull		* 670,750 lbs.	* *
Maximum Rotational Moment * * *		513,702 in.lbs.	513,702 in.lbs.
Oscillation Cylinder Pressure		900 PSI	900 PSI
Segment Cylinder Pressure	Left	580 PSI	580 PSI
	Right	400 PSI	400 PSI

* Average of 4 tests - Maximum Press Capacity - Jaws did not slip

** Unable to test - would not grip 3/8" test plates

*** Hydraulic pressure set at 900 PSI

TABLE II

JAW MOTIONS AND LIMITATIONS

		NAA Jaws	NASA Jaws
Maximum Gripping Dimension (Depth)		4"	4.25"
Maximum Fore or Aft Adjustment	- Left Fore	8"	8"
	- Left Aft	6.5"	6.5"
	- Right Fore	8"	8"
	- Right Aft	7"	7"
Maximum Angulation (Rotation)	- Left	+26.5°	+26.5°
		-26.5°	-26.5°
	- Right	+25.0°	+25.0°
		-27.0°	-27.0°
Maximum Oscillation Angulation	- Left	+12.5°	+12.5°
		-10.0°	-10.0°
	- Right	+13.0°	+13.0°
		-11.0°	-11.0°
Total Jaw Movement		45"	45"

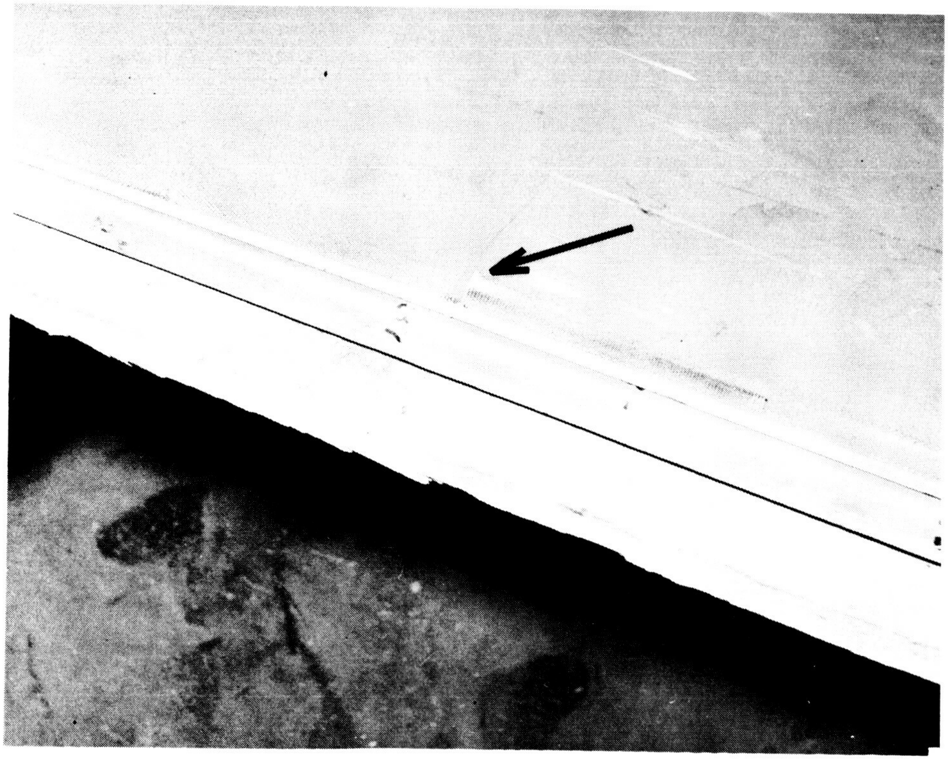


Figure No. 4 - Crack in 3/8" Test plate caused by NASA Jaws

D. TEST BLANKS

Six (6) 2219 aluminum test blanks were prepared using NASA furnished material approximately .250" thick. Eight (8) 7075 aluminum test blanks approximately .375" thick were prepared for equipment checkout. All test blanks were cut to 35" wide by 140" long. The six (6) furnished blanks and two (2) NAA blanks were marked with a 6.000" square grid system as shown in Figure No. 5.

Chemical Analysis (TABLE III) and Tensile Tests (TABLES IV and V) were run for both sets of test blanks. All plates met the applicable specifications.

TABLE III

Chemical Analysis of Representative 7075 and
2219 Aluminum Alloy Plate Stock

7075 Aluminum			2219 Aluminum		
Lab Analysis	Percent	QQ-A-250/12	Lab Analysis	Percent	MIL-A-8902
Copper	1.37	1.20-2.00	Copper	6.32	5.80-6.80
Magnesium	2.11	2.10-2.90	Magnesium	Nil	0.02 max.
Silicon	0.099	0.050 max.	Silicon	0.14	0.20 max.
Iron	0.21	0.70 max.	Iron	0.21	0.30 max.
Zinc	5.44	5.10-6.10	Zinc	Nil	0.10 max.
Titanium	Nil	0.20 max.	Titanium	0.069	0.02-0.10
Chromium	0.24	0.18-0.40	Zirconium	0.20	0.10-0.25
Manganese	Nil	0.30 max.	Manganese	0.21	0.20-0.40
			Vanadium	0.12	0.05-0.15

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66
67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132

FIGURE 5 - GRID NUMBERING SYSTEM USED ON ALL TEST SHEETS

TABLE IV

2219-T37 Plate Test Results

Bar No.	Percent Elongation in 2 Inches	Percent Uniform Elongation	Yield Strength-ksi	Ultimate Strength-ksi
NASA-1	16.6	6.4	45.1	60.1
NASA-2	17.9	7.4	45.7	60.0
NASA-3	18.6	8.1	50.0	60.0
NASA-4-1	20.8	7.8	47.1	59.8
NASA-4-2	14.5	6.5	51.2	60.6
NASA-4-3	19.0	8.0	49.0	60.0
Grand Average	17.9	7.3	48.1	60.0
Required	6.0		38.0	49.0

TABLE V

7075-T6 Plate Test Results

Bar No.	Percent Elongation in 2 Inches	Percent Uniform Elongation	Yield Strength-ksi	Ultimate Strength-ksi
NAA-1	14.5	10.0	79.5	87.0
NAA-2-1	13.6	8.6	75.3	84.7
NAA-2-2	14.5	10.0	79.9	87.1
NAA-2-3	13.4	9.1	77.7	85.9
NAA-3	14.1	9.9	78.6	86.5
NAA-4-1	14.0	8.5	77.0	85.1
NAA-4-2	14.8	9.5	78.6	86.6
NAA-4-3	15.2	10.8	78.3	86.3
Grand Average	14.3	9.5	78.1	86.1
Required	8.0		66.0	77.0

E. FORMING TESTS

1. Test Procedures

All test plates were mounted in the Stretch Press with grid square No. 1 in the upper left hand corner. Seventy-two (72) strain gages were mounted on each test blank. Gages were mounted on both front and back on the test blank ends and on the front only in the center of the test blanks. Figure No. 6 shows part number NAA-3 mounted in the stretch press using the NAA jaws. The close-up view of the center of part NAA-3 (Figure No. 7) shows the X and Y orientation of the strain gages.

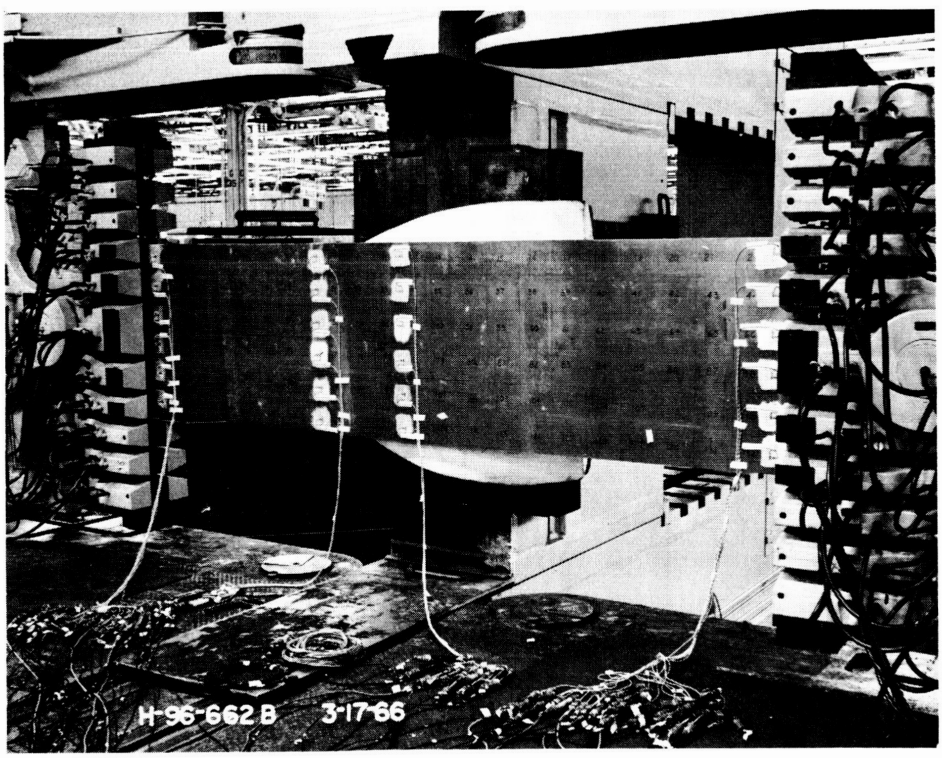


Figure No. 6 - Part No. NAA-3 Mounted in NAA Jaws

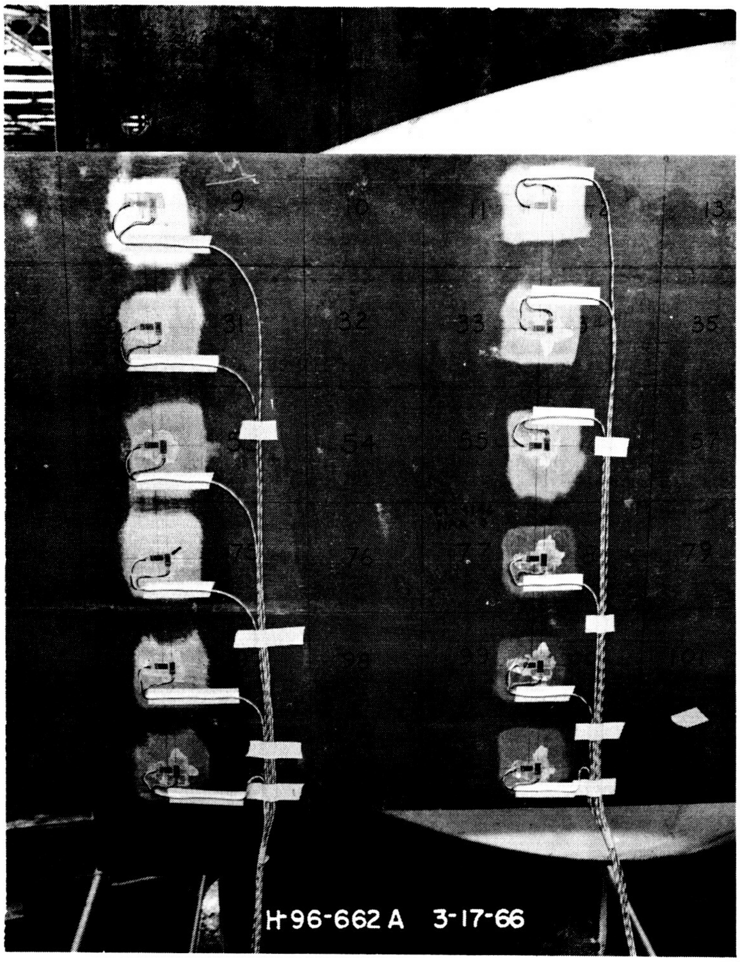


Figure No. 7 - Strain Gage Mounting,
Front Center of Test Blank

Test blanks pulled with the NASA jaws were mounted in the same position as those pulled with NAA jaws (Figure No. 8). Part Number NASA-4-1 is shown in Figure No. 9 at the end of the stretch cycle. The right jaw has been contoured to approximate the contour of the large end of the die. The outline of the small end of the die is very apparent in the left hand portion of the photograph.

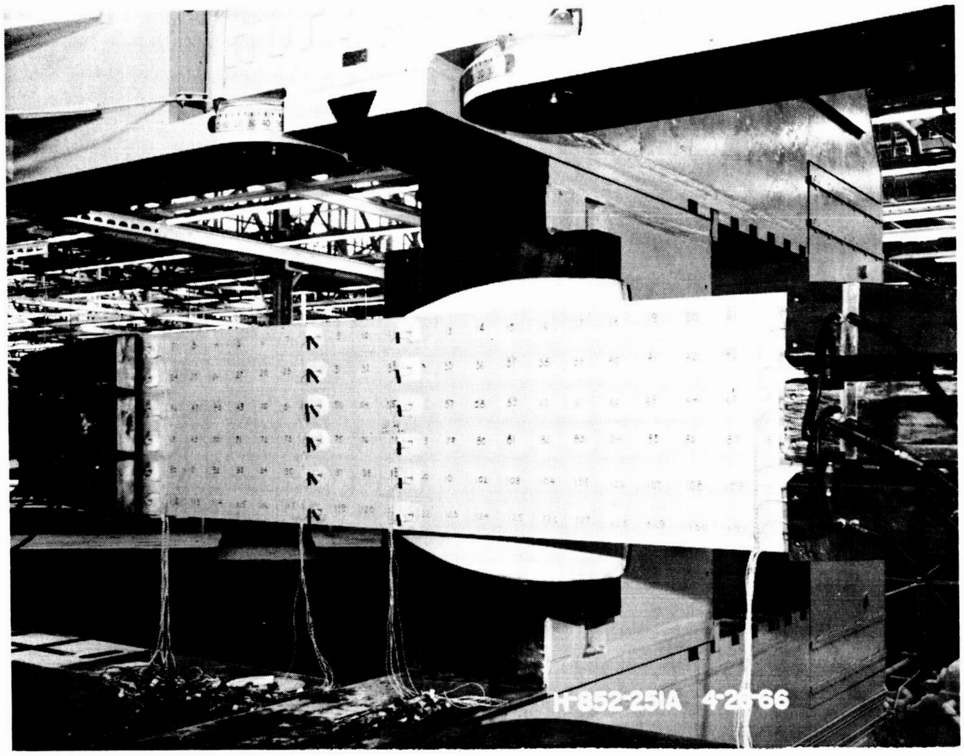


Figure No. 8 - Part No. NASA-4-1
Mounted in NASA Jaws

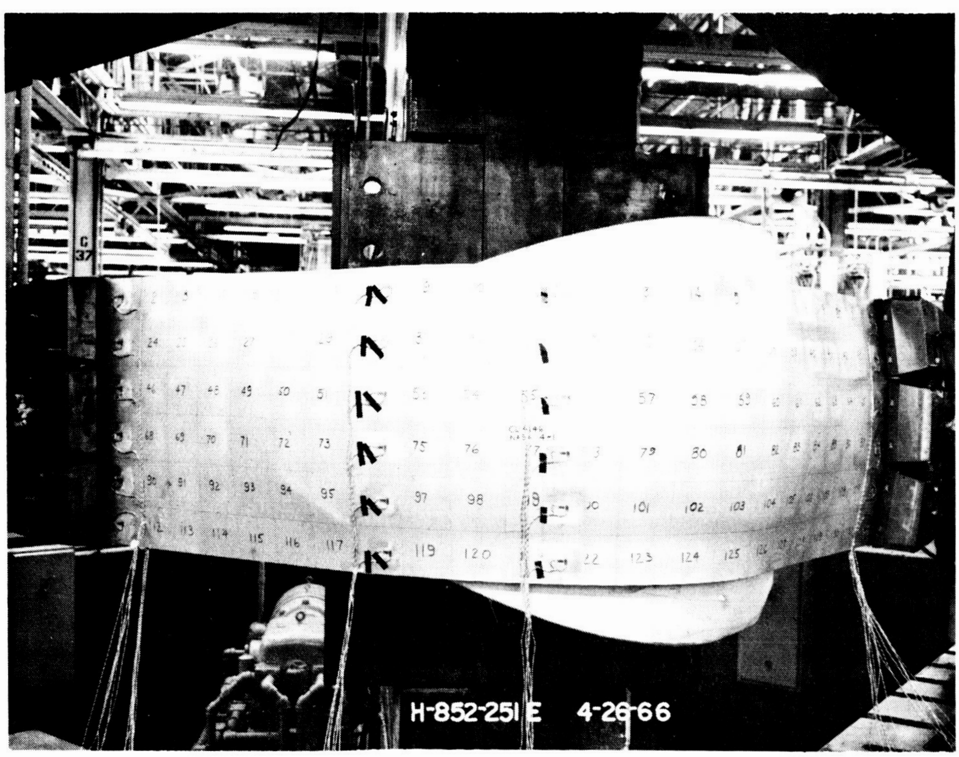


Figure No. 9 - Part No. NASA-4-1
After Forming

Data from all strain gages was continuously recorded during the forming of all instrumented test parts. The overall view in Figure No. 10 shows the method of connecting the strain gages to the high speed oscillographic recording equipment. Details of strain recordings are discussed in Section III-F.

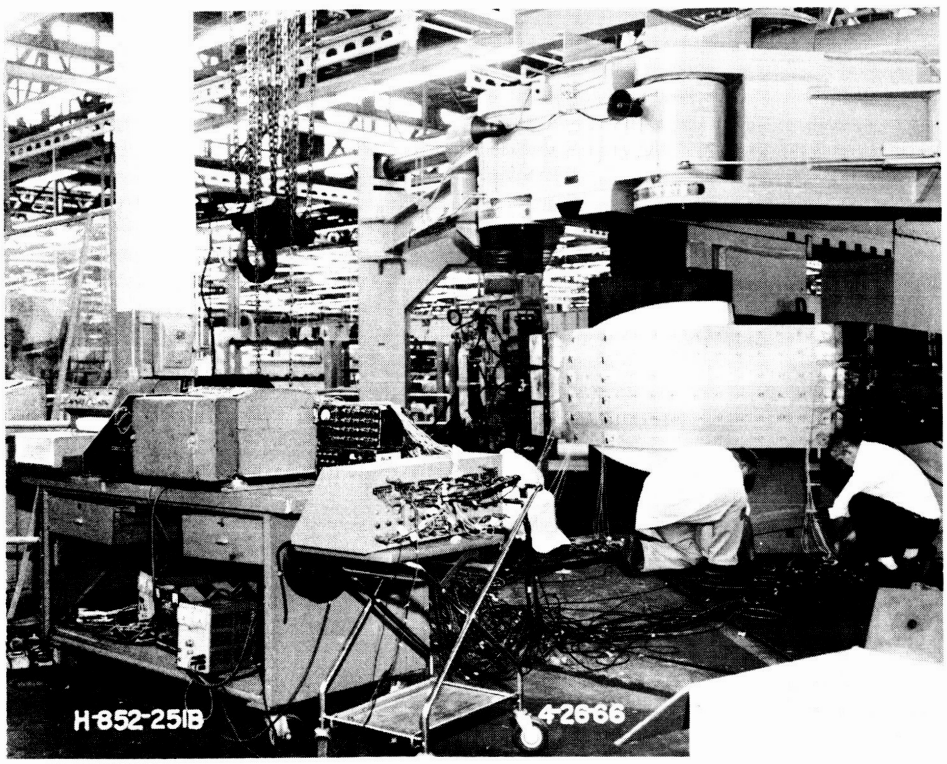


Figure No. 10 - Strain Data Recording Equipment Connected to Test Blank

Loading of test blanks and press positions are tabulated below (TABLE VI). Cross sectional loading of the test blanks was gradually increased as the tests proceeded, and in general, the degree of forming achieved increased as pressure increased.

TABLE VI

Test Blank Loading Data

Part	Jaw	Total Load	Test Blank Loading	Press Arm Position Left	Press Arm Position Right
NASA-1	NAA	430,000 lbs.	49,143 psi	41°	50°
NASA-2	NAA	440,000	50,286	48°	55°
NASA-3	NASA	450,000	49,669	47°	50°
NASA-4-1	NASA	460,000	49,784	47°	52°
NASA-4-2	NASA	460,000	50,941	50°	50°
NASA-4-3	NASA	462,000	51,563	47°	52°
NAA-2-1	NAA	665,000	51,630	40°	50°
NAA-2-2	NAA	667,000	51,786	45°	53°
NAA-2-3	NAA	677,000	52,562	47°	50°
NAA-3	NAA	674,000	52,329	47°	52°

2. <u>Forming Results</u>

The degree of forming achieved on all test blanks is shown pictorially in Figure Nos. 11 through 20. This series of photographs was taken against a 4' X 12' backdrop divided into 12" grid squares. All parts are set with the top of the test blank against the backdrop.

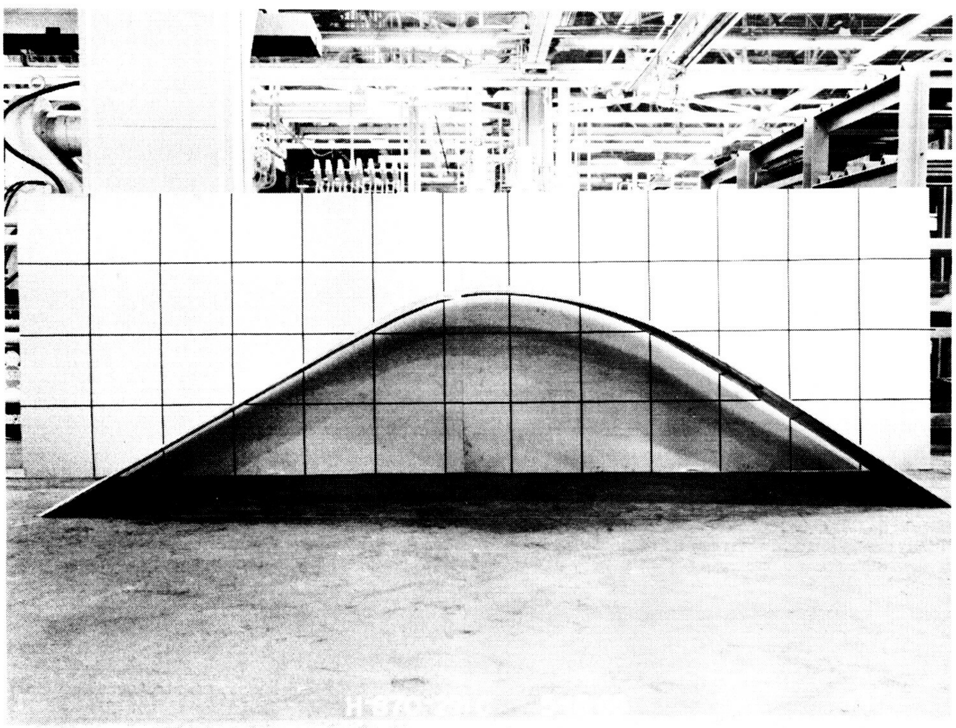


Figure No. 11 - Part No. NAA-2-1

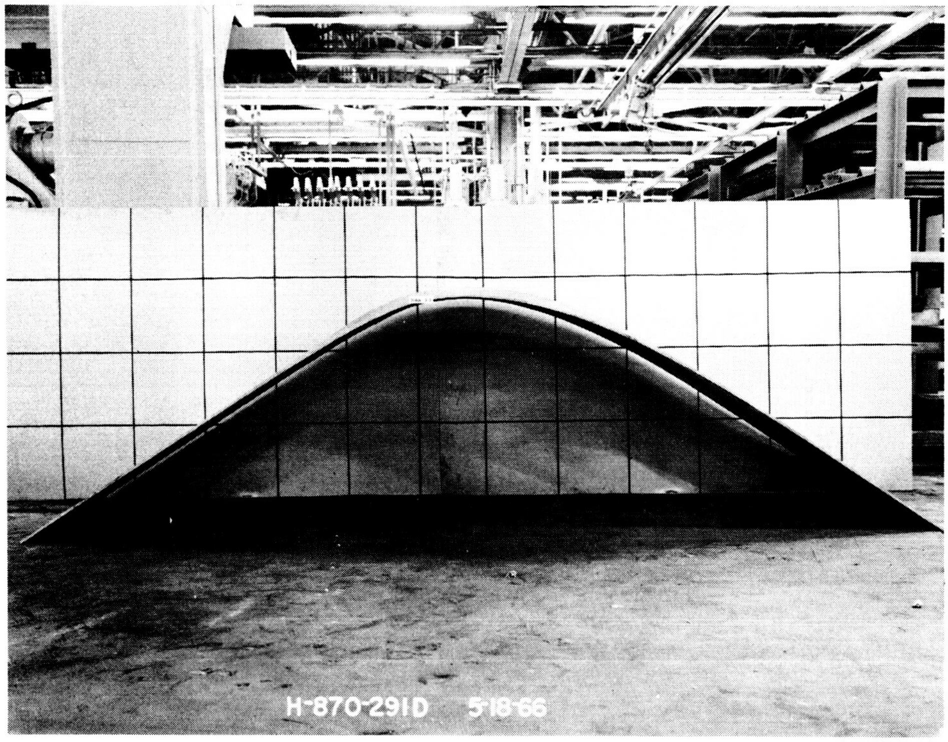


Figure No. 12 - Part No. NAA-2-2

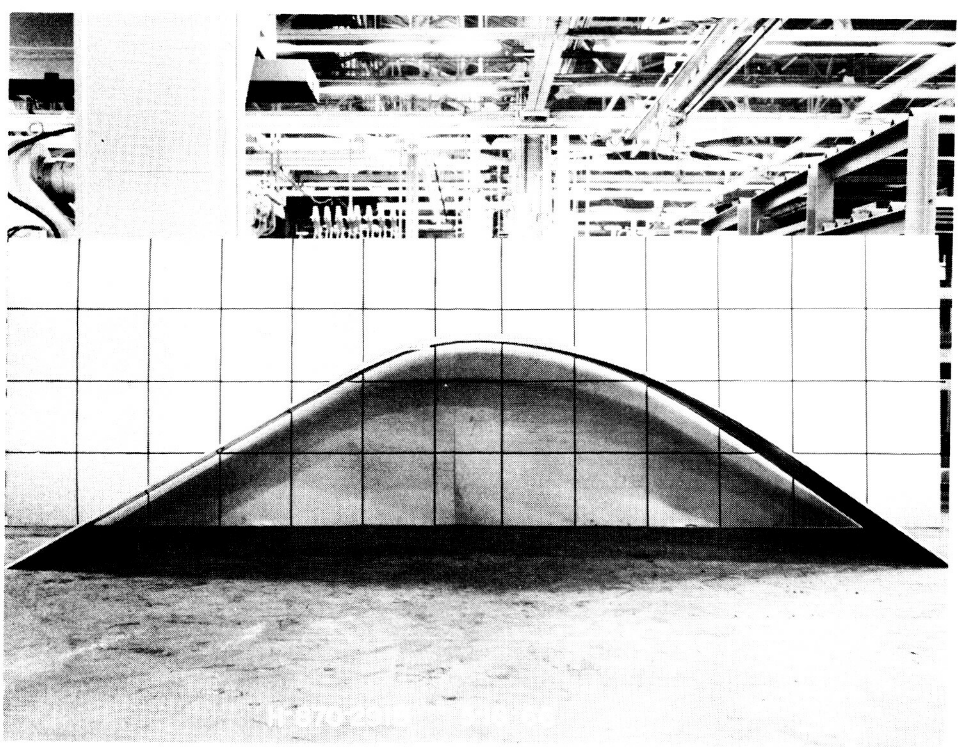


Figure No. 13 - Part No. NAA-2-3

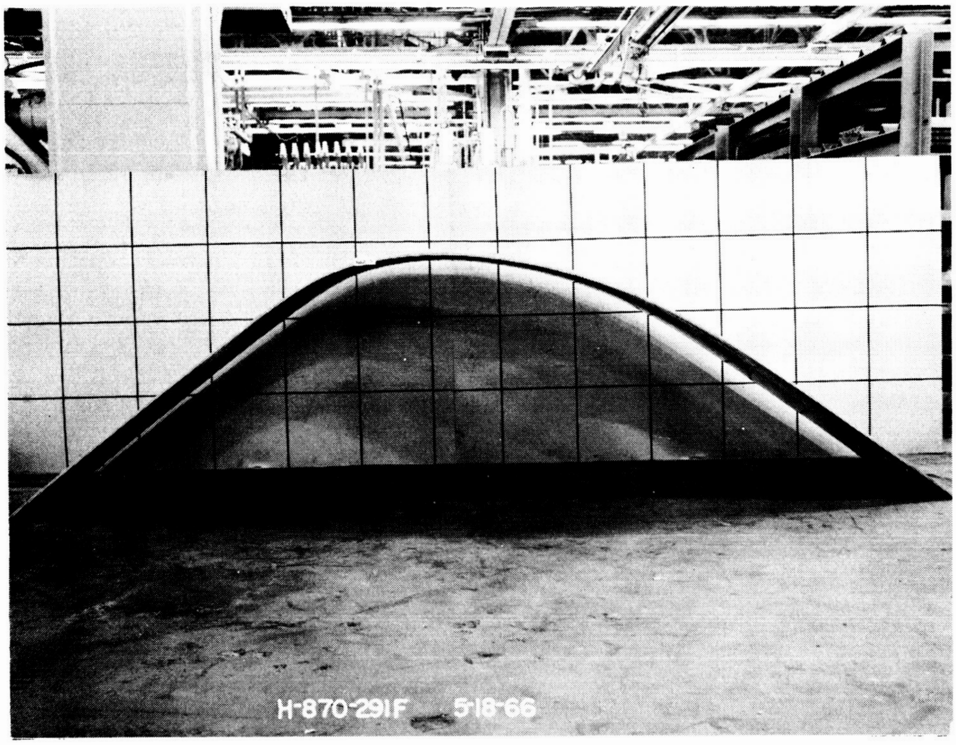


Figure No. 14 - Part NAA-3

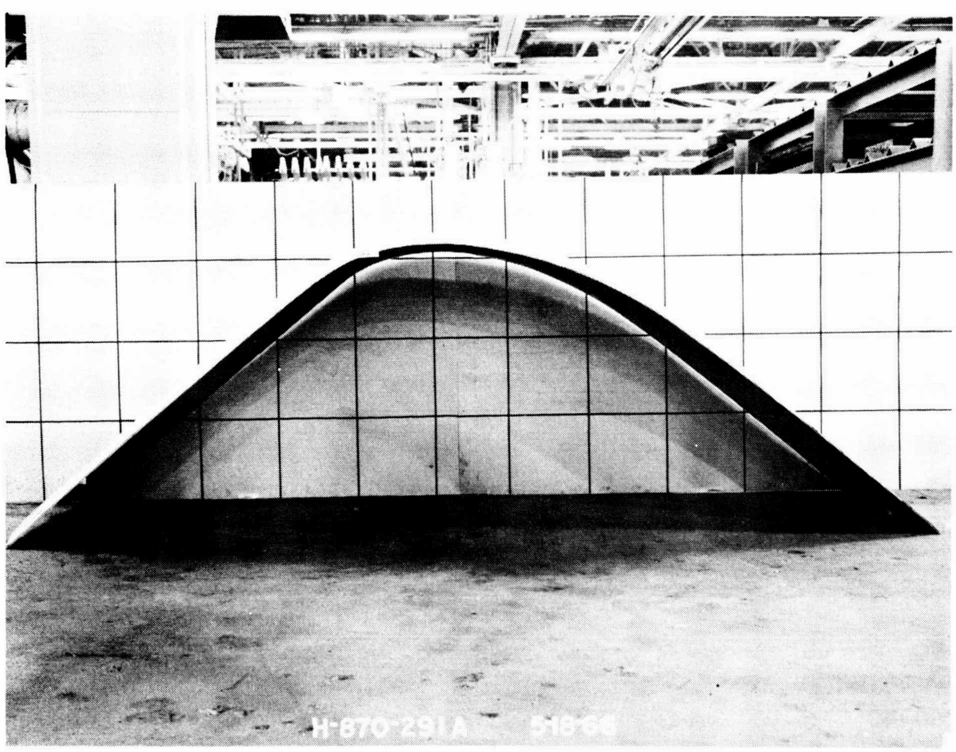


Figure No. 15 - Part No. NASA-1

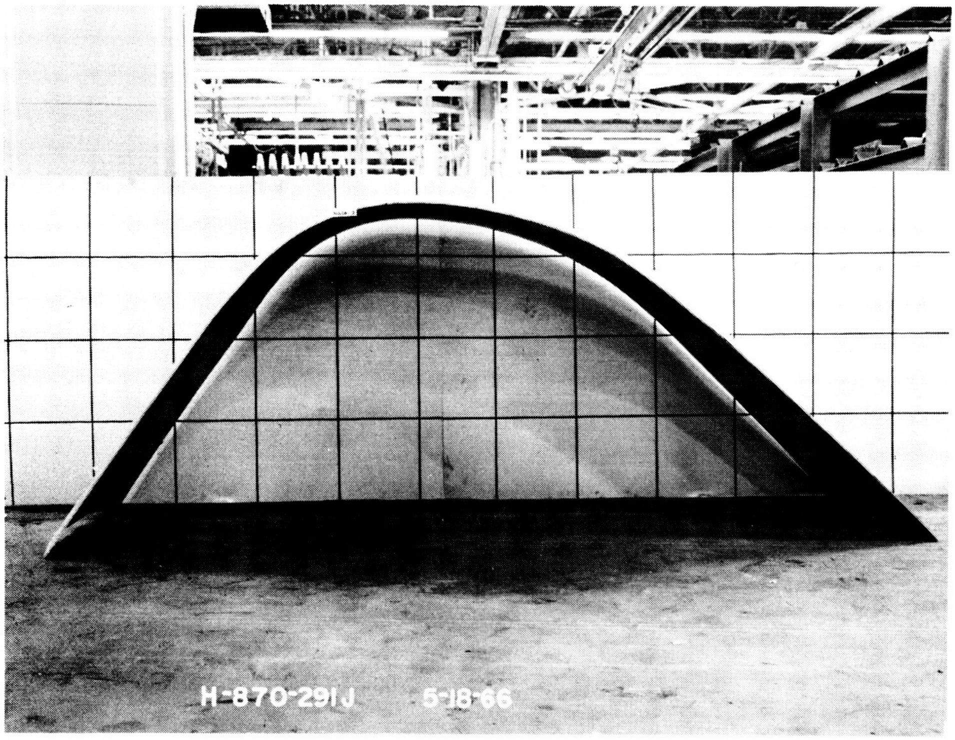


Figure No. 16 - Part No. NASA-2

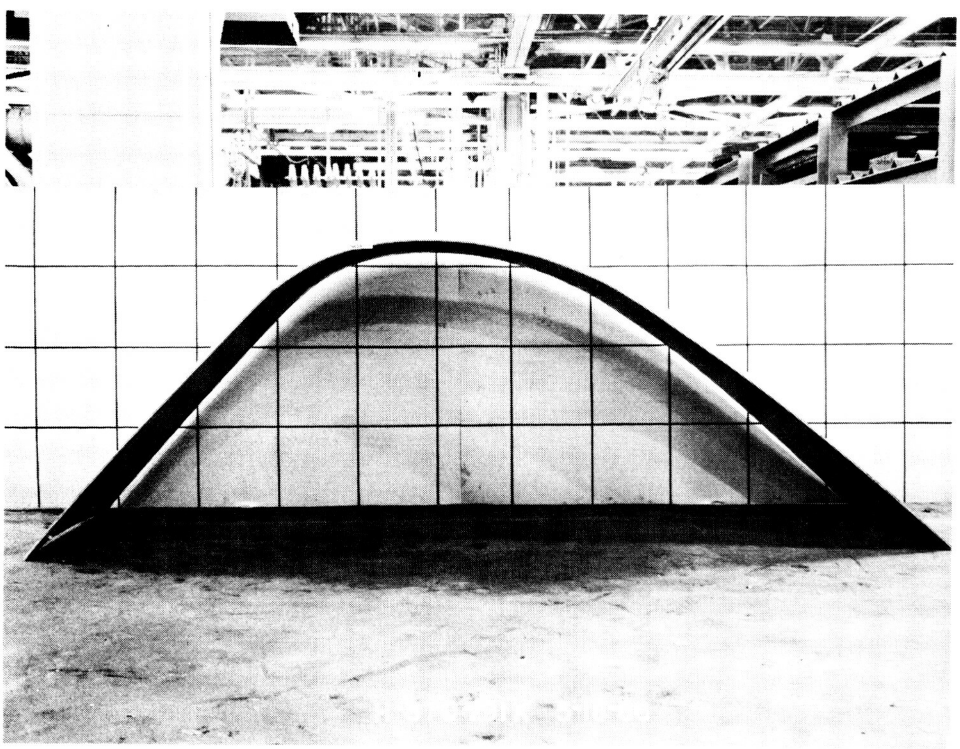


Figure No. 17 - Part No. NASA-3

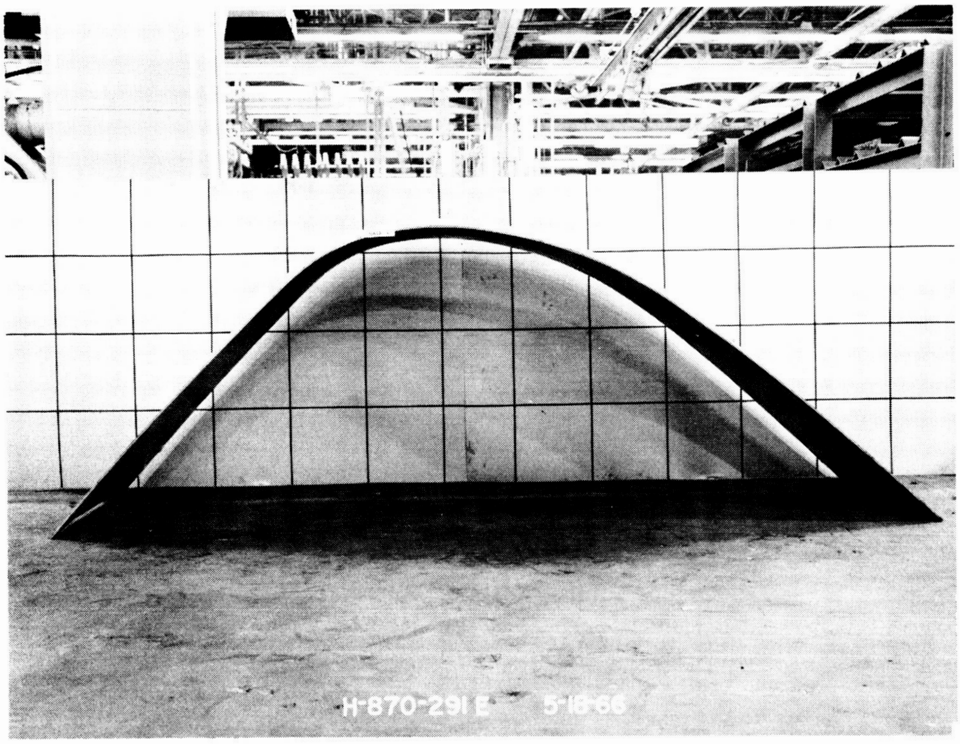


Figure No. 18 - Part No. NASA-4-1

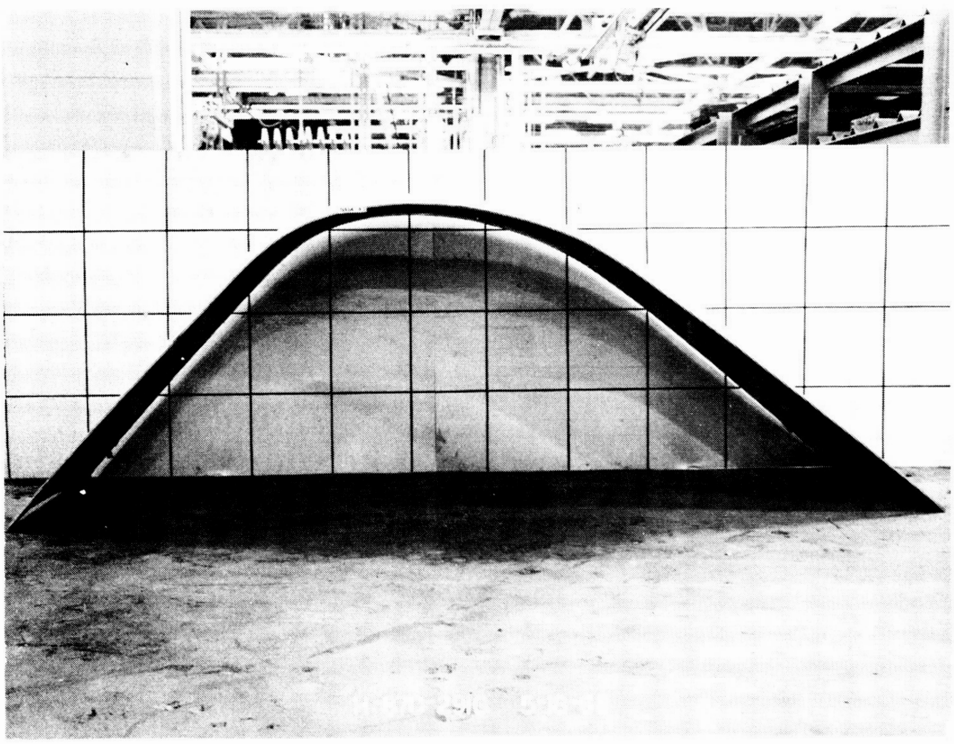


Figure No. 19 - Part No. NASA-4-2

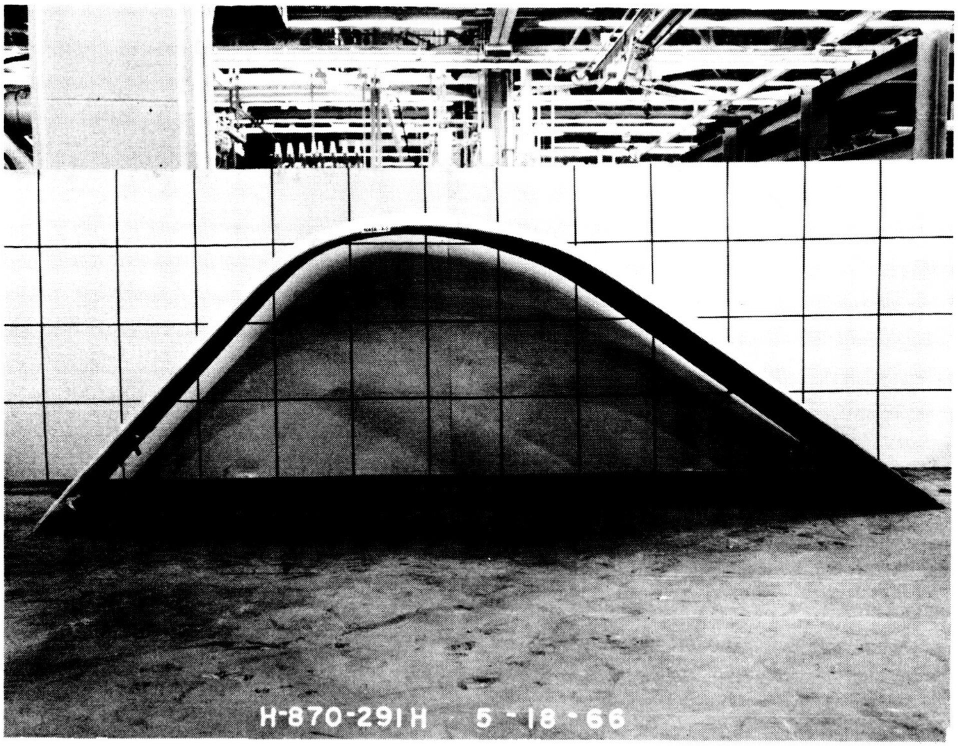


Figure No. 20 - Part No. NASA-4-3

3. Dimensional Changes

Before stretch forming, the thickness of each test blank was measured using a Vidigage Thickness Gage. After forming, each 6" grid square in the die contact area was again measured (Figure No. 21) to check reduction in thickness. Reductions ranged from .008" to .015", evenly spread between NAA and NASA jaws, so that no particular difference in performance was noted in this area.

Figure No. 21 - Vidigage Thickness Testing of Test Parts

Springback data was also recorded, where possible, using the laminated contour gage (Figure No. 3). As was the case with reduction in thickness, there was no significant difference between springback using the NAA or NASA jaws. Detailed thickness and springback readings on all test blanks are displayed in Figures 22 through 28.

Final dimensions of each 6" grid square in the die contact area were measured and recorded. These results are displayed in Figures 29 through 35. Again, there appeared to be no significant difference in the performance of the two types of jaws.

Grid No. 6											Grid No. 17
.366	.365	.366	.365	.365	.366	.365	.366	.366	.365	.367	.366
.366	.365	.366	.366	.365	.365	.364	.366	.365	.364	.366	.367
.366	.366	.365	.366	.365	.366	.365	.366	.365	.364	.366	.366
.367	.368	.368	.368	.368	.368	.368	.367	.366	.367	.368	.367
Grid No. 116											Grid No. 127

NOMINAL STARTING THICKNESS .368

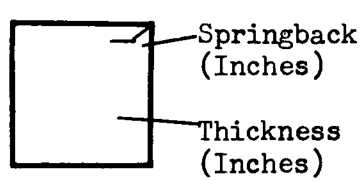


FIGURE 22 - THICKNESS AND SPRINGBACK DATA. PART NO. NAA-3

Grid No. 6								.065			Grid No. 17
.248	.248	.246	.247	.245	.243	.244	.244	.243	.242	.245	.247
.247	.248	.246	.245	.243	.243	.240	.238	.240	.241	.245	.245
.246	.247	.246	.245	.240	.050 .242	.240	.238	.240	.241	.050 .245	.245
.247	.247	.246	.246	.243	.243	.240	.241	.241	.242	.245	.246
Grid No. 116								.080			Grid No. 127

NOMINAL STARTING THICKNESS .250

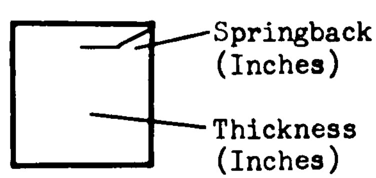


FIGURE 23 – THICKNESS AND SPRINGBACK DATA. PART NO. NASA-1

Grid No. 6								.140			Grid No. 17
.248	.246	.248	.247	.248	.249	.248	.246	.246	.248	.245	.245
.243	.242	.242	.245	.247	.246	.247	.246	.243	.242	.244	.246
.245	.248	.245	.247	.248	.180 .247	.248	.247	.245	.242	.046 .244	.245
.247	.249	.249	.249	.248	.246	.249	.250	.247	.247	.248	.248
Grid No. 116								.171			Grid No. 127

NOMINAL STARTING THICKNESS .250

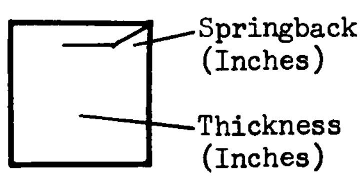


FIGURE 24 - THICKNESS AND SPRINGBACK DATA. PART NO. NASA-2

Grid No. 6											Grid No. 17
.256	.254	.255	.255	.257	.260	.260	.259	.253	.255	.253	.256
.256	.256	.252	.254	.253	.258	.259	.258	.253	.252	.251	.255
.256	.255	.252	.254	.254	.257	.260	.259	.255	.254	.253	.257
.258	.256	.253	.255	.258	.260	.262	.262	.260	.259	.259	.260
Grid No. 116											Grid No. 127

NOMINAL STARTING THICKNESS .259

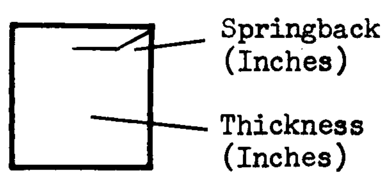


FIGURE 25 - THICKNESS AND SPRINGBACK DATA. PART NO. NASA-3

Grid No. 6								.042			Grid No. 17
.264	.264	.263	.262	.264	.261	.262	.262	.260	.258	.258	.259
.264	.263	.263	.261	.261	.259	.260	.260	.257	.256	.257	.248
.264	.263	.264	.261	.240 .261	.261	.260	.260	.257	.256	.101 .257	.258
.265	.264	.264	.264	.263	.264	.264	.263	.261	.260	.258	.260
Grid No. 116								.078			Grid No. 127

NOMINAL STARTING THICKNESS .264

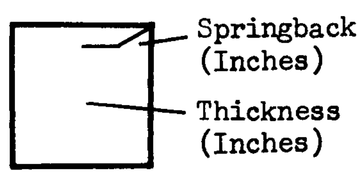


FIGURE 26 – THICKNESS AND SPRINGBACK DATA – PART NO. NASA 4-1

Grid No. 6											Grid No. 17
.254	.255	.254	.255	.256	.255	.251	.251	.250	.249	.250	.252
.252	.254	.254	.255	.255	.253	.250	.250	.246	.245	.248	.251
.252	.254	.253	.255	.253	.254	.250	.250	.246	.244	.249	.252
.254	.255	.256	.255	.255	.254	.254	.253	.250	.247	.252	.253
Grid No. 116											Grid No. 127

NOMINAL STARTING THICKNESS .258

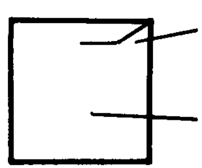


FIGURE 27 - THICKNESS AND SPRINGBACK DATA. PART NO. NASA 4-2

Grid No. 6									.112		Grid No. 17
.250	.249	.248	.249	.251	.249	.247	.247	.247	.246	.246	.247
.249	.249	.249	.248	.249	.248	.247	.246	.244	.243	.244	.245
.249	.248	.010 .248	.248	.249	.249	.247	.247	.245	.244	.241	.031 .241
.250	.250	.251	.252	.249	.250	.249	.249	.247	.245	.247	.247
Grid No. 116								.140			Grid No. 127

NOMINAL STARTING THICKNESS .256

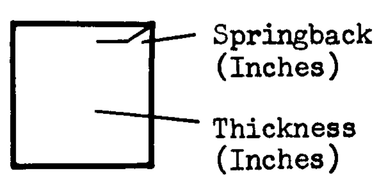


FIGURE 28 - THICKNESS AND SPRINGBACK DATA. PART NO. NASA 4-3

	Grid No. 6											Grid. No. 17
5.990	6.020 / 5.980	6.000 / 5.970	6.010 / 5.980	6.010 / 5.980	6.010 / 5.980	6.010 / 5.980	6.050 / 5.960	6.020 / 5.960	6.040 / 5.970	6.040 / 5.980	6.020 / 5.980	6.000 / 5.980
6.000	6.000 / 5.990	6.050 / 5.990	6.050 / 5.990	6.050 / 5.990	6.050 / 5.990	6.050 / 5.970	6.025 / 5.990	6.090 / 5.980	6.070 / 5.980	6.170 / 5.990	6.070 / 5.980	6.000 / 5.990
5.990	6.030 / 5.980	6.050 / 5.980	6.070 / 5.980	6.070 / 5.980	6.080 / 5.980	6.080 / 5.990	6.150 / 5.940	6.125 / 5.980	6.220 / 5.980	6.220 / 5.980	6.080 / 5.980	6.010 / 5.980
5.990	6.030 / 5.970	6.030 / 5.970	6.040 / 5.970	6.040 / 5.970	6.040 / 5.970	6.020 / 5.970	6.070 / 5.960	6.060 / 5.950	6.120 / 5.950	6.120 / 5.970	6.050 / 5,970	6.010 / 5.980
	Grid No. 116	6.010	6.010	6.010	6.010	6.000	6.020	6.030	6.030	6.030	6.010	Grid No. 127

FIGURE 29 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA PART NO. NAA-3

	Grid No. 6											Grid No. 17
5.980	6.050 / 5.990	6.100 / 5.980	6.090 / 5.980	6.070 / 5.970	6.090 / 5.970	6.120 / 5.960	6.120 / 5.950	6.125 / 5.960	6.125 / 5.970	6.025 / 5.960	6.080 / 5.960	6.080 / 5.960
5.980	6.010 / 5.980	6.025 / 5.960	6.170 / 5.960	6.170 / 5.950	6.200 / 5.950	6.220 / 5.960	6.240 / 5.950	6.300 / 5.960	6.300 / 5.960	6.025 / 5.940	6.180 / 5.940	6.120 / 5.960
5.980	6.125 / 5.980	6.150 / 5.960	6.200 / 5.960	6.200 / 5.960	6.240 / 5.950	6.250 / 5.960	6.280 / 5.950	6.350 / 5.950	6.330 / 5.960	6.280 / 5.940	6.190 / 5.940	6.125 / 5.960
5.990	6.100 / 5.980	6.125 / 5.980	6.160 / 5.970	6.160 / 5.980	6.180 / 5.960	6.180 / 5.970	6.200 / 5.950	6.250 / 5.950	6.270 / 5.950	6.230 / 5.970	6.140 / 5.970	6.090 / 5.970
	Grid No. 116	6.060	6.060	6.060	6.050	6.050	6.050	6.060	6.080	6.070	6.050	Grid No. 127

FIGURE 30 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA PART NO. NASA-1

	Grid No. 6											Grid No. 17
5.970	6.050 / 5.990	6.080 / 5.980	6.120 / 5.960	6.080 / 5.970	6.070 / 5.960	6.070 / 5.960	6.080 / 5.960	6.100 / 5.950	6.150 / 5.930	6.150 / 5.930	6.125 / 5.950	6.120 / 5.920
5.960	6.160 / 5.960	6.160 / 5.970	6.180 / 5.960	6.170 / 5.960	6.060 / 5.970	6.160 / 5.960	6.160 / 5.960	6.230 / 5.940	6.300 / 5.930	6.330 / 5.930	6.260 / 5.930	6.220 / 5.910
5.960	6.170 / 5.980	6.150 / 5.960	6.180 / 5.960	6.190 / 5.960	6.190 / 5.970	6.180 / 5.970	6.150 / 5.950	6.260 / 5.950	6.360 / 5.930	6.320 / 5.950	6.320 / 5.930	6.220 / 5.930
5.970	6.120 / 5.980	6.130 / 5.970	6.140 / 5.970	6.140 / 5.960	6.150 / 5.970	6.120 / 5.960	6.140 / 5.950	6.220 / 5.940	6.260 / 5.930	6.280 / 5.950	6.250 / 5.950	6.210 / 5.930
	Grid No. 116	6.060	6.060	6.050	6.050	6.040	6.040	6.050	6.050	6.070	6.090	Grid No. 127

FIGURE 31 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA. PART NO. NASA-2

	Grid No. 6											Grid No. 17
5.990	6.050 5.990	6.060 5.990	6.120 5.980	6.070 5.980	6.070 5.970	6.080 5.980	6.070 5.980	6.080 5.970	6.090 5.970	6.120 5.970	6.120 5.960	6.070 5.950
5.980	6.125 5.980	6.125 5.980	6.150 5.960	6.170 5.970	6.170 5.970	6.150 5.970	6.150 5.980	6.190 5.960	6.240 5.960	6.280 5.950	6.250 5.930	6.180 5.930
5.970	6.140 5.980	6.130 5.970	6.160 5.970	6.190 5.960	6.200 5.970	6.180 5.970	6.170 5.970	6.200 5.970	6.270 5.960	6.320 5.960	6.280 5.940	6.230 5.930
5.980	6.110 5.990	6.090 5.990	6.125 5.980	6.125 5.970	6.160 5.970	6.125 5.980	6.125 5.970	6.140 5.960	6.220 5.950	6.230 5.960	6.230 5.960	6.160 5.960
	Grid No. 116	6.030	6.050	6.030	6.050	6.030	6.030	6.030	6.040	6.060	6.070	Grid No. 127

FIGURE 32 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA PART NO. NASA-3

	Grid No. 6											Grid No. 17
5.990	6.110 / 5.990	6.120 / 5.990	6.140 / 5.970	6.150 / 5.980	6.150 / 5.970	6.190 / 5.960	6.180 / 5.960	6.200 / 5.960	6.280 / 5.960	6.300 / 5.950	6.250 / 5.950	6.125
5.990	6.100 / 5.990	6.125 / 5.960	6.160 / 5.960	6.185 / 5.960	6.185 / 5.960	6.200 / 5.960	6.200 / 5.960	6.250 / 5.960	6.310 / 5.950	6.345 / 5.940	6.280 / 5.940	6.150
5.990	6.080 / 5.990	6.100 / 5.980	6.125 / 5.980	6.125 / 5.960	6.140 / 5.970	6.140 / 5.970	6.140 / 5.970	6.170 / 5.960	6.250 / 5.950	6.260 / 5.940	6.220 / 5.940	6.110
5.990	6.020 / 5.990	6.050 / 5.980	6.050 / 5.980	6.050 / 5.970	6.050 / 5.960	6.060 / 5.960	6.040 / 5.970	6.040 / 5.970	6.060 / 5.950	6.060 / 5.950	6.070 / 5.950	6.020
	Grid No. 116											Grid No. 127

FIGURE 33 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA PART NO. NASA 4-1

	Grid No. 6											Grid No. 17
5.960	6.060 / 5.980	6.080 / 5.990	6.150 / 5.960	6.110 / 5.960	6.080 / 5.970	6.100 / 5.970	6.080 / 5.960	6.120 / 5.960	6.130 / 5.950	6.150 / 5.960	6.140 / 5.950	6.070 / 5.950
5.950	6.160 / 5.970	6.140 / 5.975	6.170 / 5.955	6.190 / 5.950	6.170 / 5.970	6.170 / 5.970	6.170 / 5.970	6.220 / 5.960	6.270 / 5.950	6.320 / 5.950	6.289 / 5.935	6.190 / 5.930
5.950	6.200 / 5.970	6.140 / 5.970	6.190 / 5.955	6.220 / 5.950	6.200 / 5.960	6.200 / 5.970	6.190 / 5.970	6.230 / 5.960	6.300 / 5.940	6.375 / 5.960	6.320 / 5.930	6.220 / 5.980
5.960	6.140 / 5.970	6.120 / 5.980	6.150 / 5.960	6.160 / 5.960	6.150 / 5.960	6.170 / 5.980	6.140 / 5.980	6.180 / 5.960	6.240 / 5.950	6.300 / 5.950	6.270 / 5.960	6.180 / 5.950
	Grid No. 116	6.050	6.080	6.050	6.045	6.070	6.030	6.050	6.066	6.070	6.110	Grid No. 127

FIGURE 34 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA PART NO. NASA 4-2

	Grid No. 6											Grid No. 17
5.960	5.970	5.985	5.960	5.970	5.970	5.970	5.960	5.970	5.980	5.960	5.950	5.940
5.960	6.240 / 5.960	6.240 / 5.970	6.220 / 5.930	6.200 / 5.970	6.220 / 5.970	6.240 / 5.970	6.230 / 5.970	6.250 / 5.980	6.250 / 5.980	6.320 / 5.960	6.315 / 5.940	6.280 / 5.920
5.950	6.250 / 5.950	6.330 / 5.960	6.220 / 5.950	6.230 / 5.960	6.240 / 5.960	6.240 / 5.960	6.250 / 5.960	6.250 / 5.980	6.280 / 5.960	6.360 / 5.950	6.360 / 5.930	6.320 / 5.900
5.960	6.190 / 5.980	6.220 / 5.990	6.190 / 5.970	6.190 / 5.980	6.200 / 5.980	6.220 / 5.970	6.240 / 5.980	6.220 / 5.980	6.230 / 5.970	6.280 / 5.980	6.300 / 5.960	6.250 / 5.950
	Grid No. 116	6.100	6.180	6.100	6.100	6.100	6.100	6.090	6.060	6.110	6.325	Grid No. 127

FIGURE 35 - FINAL DIMENSIONS OF 6.000" GRID SQUARES IN DIE CONTACT AREA PART NO. NASA 4-3

F. STRAIN MEASUREMENT AND RESULTS

1. Strain Gages

Seven test panels instrumented with Micromeasurement Type EP-08-250BB-120 high elongation strain gages. This strain gage is an annealed constantan alloy foil on an epoxy backing with strain limitations of approximately 15%. Each specimen received identical treatment with respect to the number and location of strain gages, curing history, and the type of readout equipment utilized.

Strain gages were located on each end of the panel, front and back, to determine the strain distribution across the panel near the jaw contact area. Other gages were located on the front of the panels in the area of die contact to establish maximum strain areas. Gage locations are shown in Figure No. 36 and pictorially in Figure Nos. 6 and 7.

Three panels (NAA 3, NASA 1, and NASA 2) were formed with NAA jaws. The remaining four instrumented panels (NASA 3, NASA 4-1, NASA 4-2, and NASA 4-3) were formed with the NASA jaws.

2. Recording Equipment

The instrumented panels were each installed in the Model 60 Hufford stretch press over the customer furnished die. A continuous strain history was recorded on two 50-channel Midwestern and Consolidated oscillographs as the load was applied to stretch and form the panels (Figure No. 10).

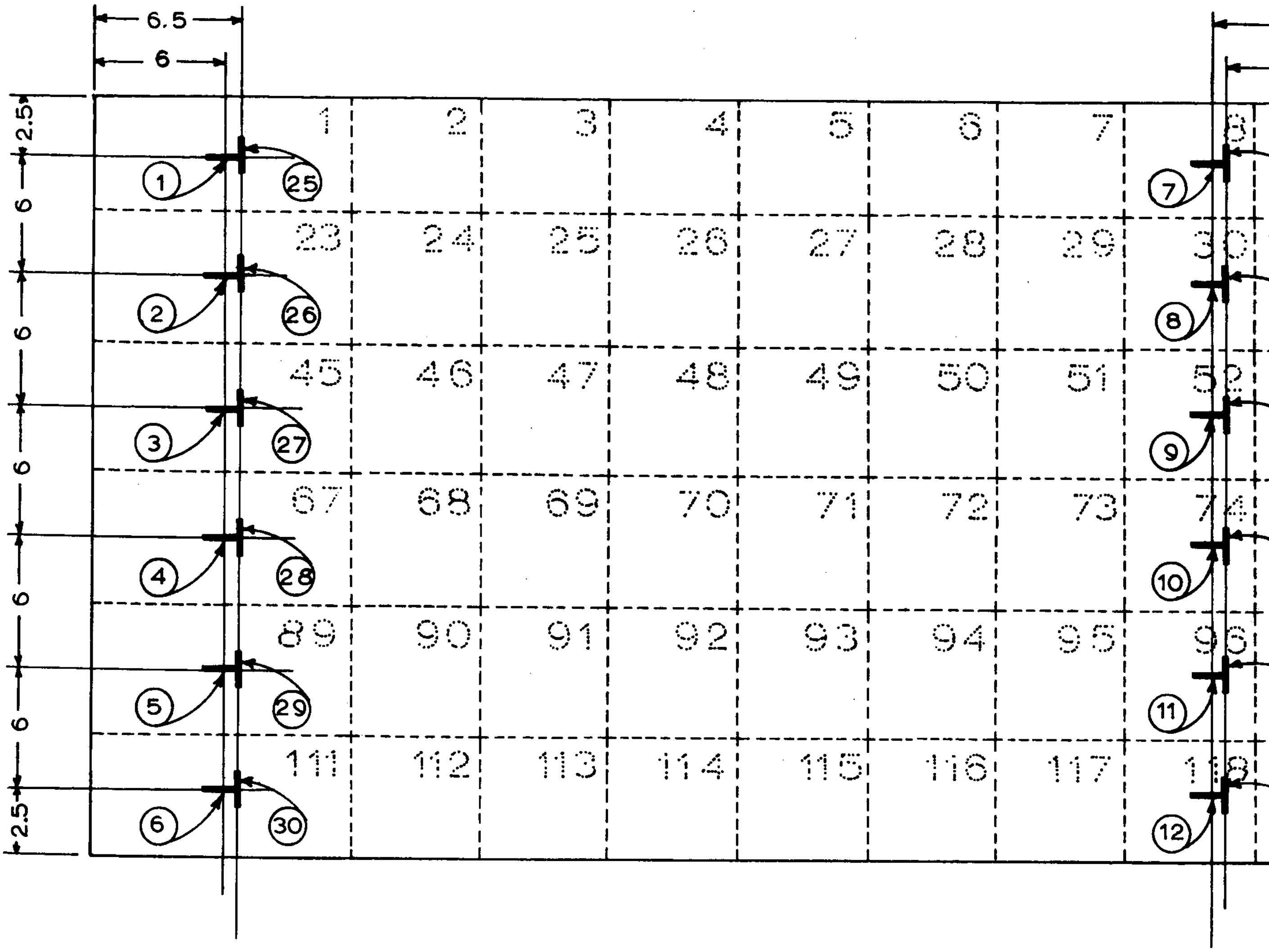
3. Results

The strain data acquired during this series of tests indicates that both sets of jaws developed a very uniform strain distribution near the jaw contact area. As indicated in the strain curves shown in Figure Nos. 37 thru 51 there was a minimum amount of spanwise bending in the jaw area to add to the total strain concentration. Gripping action as indicated by the strain gages was very uniform across the width of all the panels.

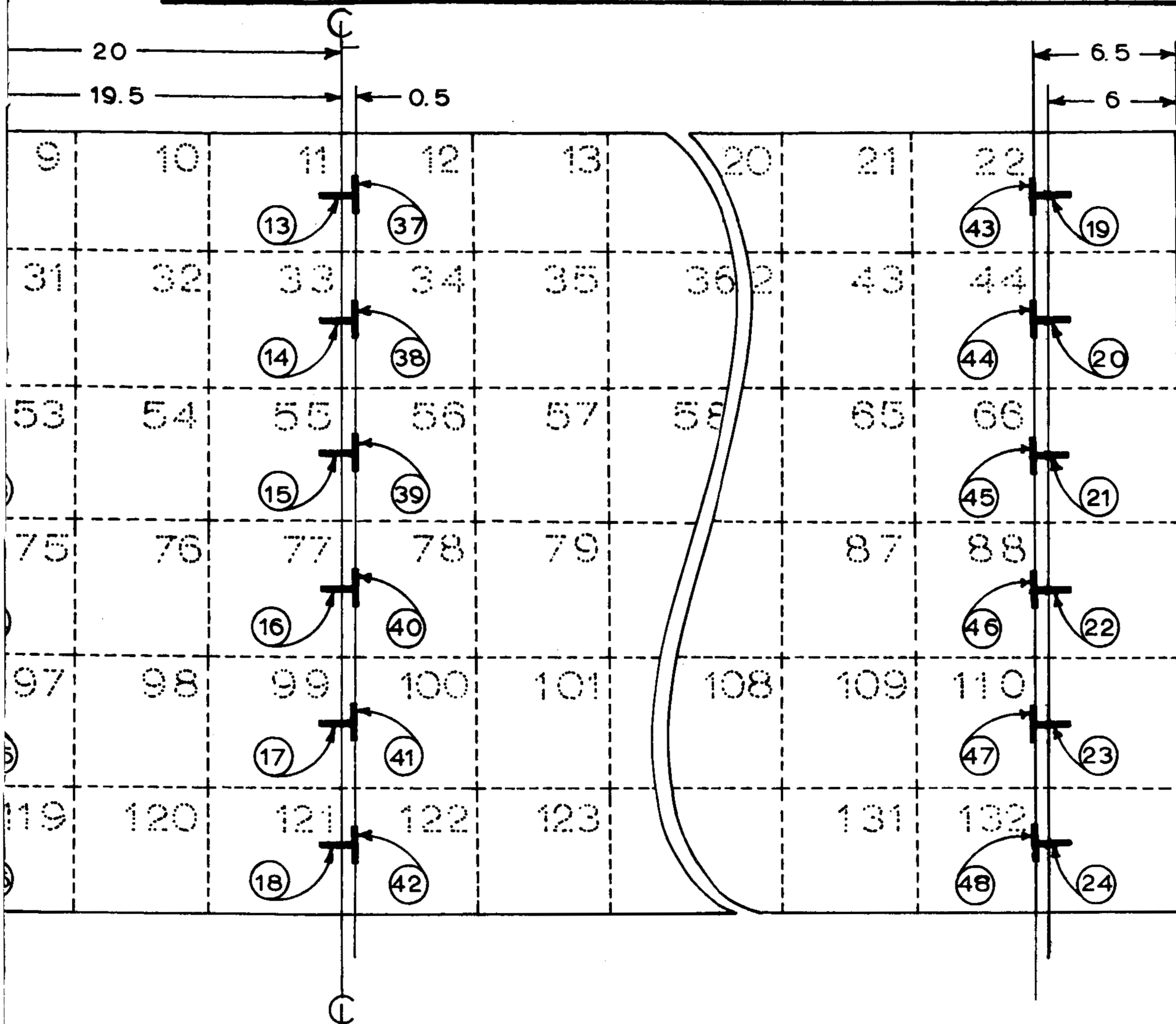
Cordwise bending as indicated by cordwise gages in the jaw contact area show that the NAA jaws introduced more cordwise bending strain which is verified by the higher limits of jaw articulation encountered.

With this exception only there were no significant differences in the strain distribution patterns developed by the two sets of jaws.

Because each panel was not loaded to the exact same load and because the range of strain indicated is above the elastic limit, the data from panel to panel is not directly comparable.


6.5
6
2.5
6
6
6
6
6
2.5
1 2 3 4 5 6 7 8
23 24 25 26 27 28 29 30
45 46 47 48 49 50 51 52
67 68 69 70 71 72 73 74
89 90 91 92 93 94 95 96
111 112 113 114 115 116 117 118
1 2 3 4 5 6 7 8 9 10 11 12
25 26 27 28 29 30

47-1

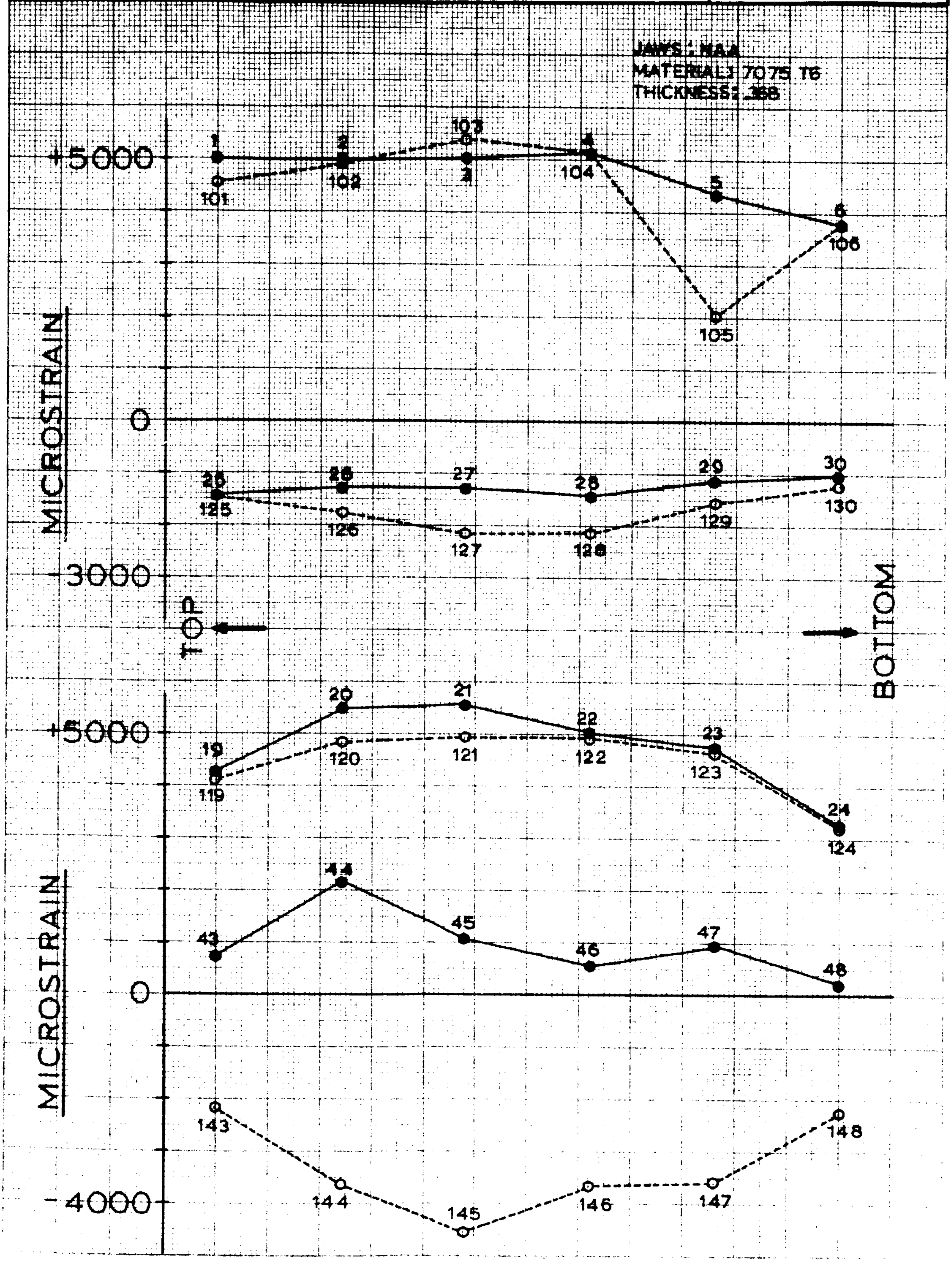


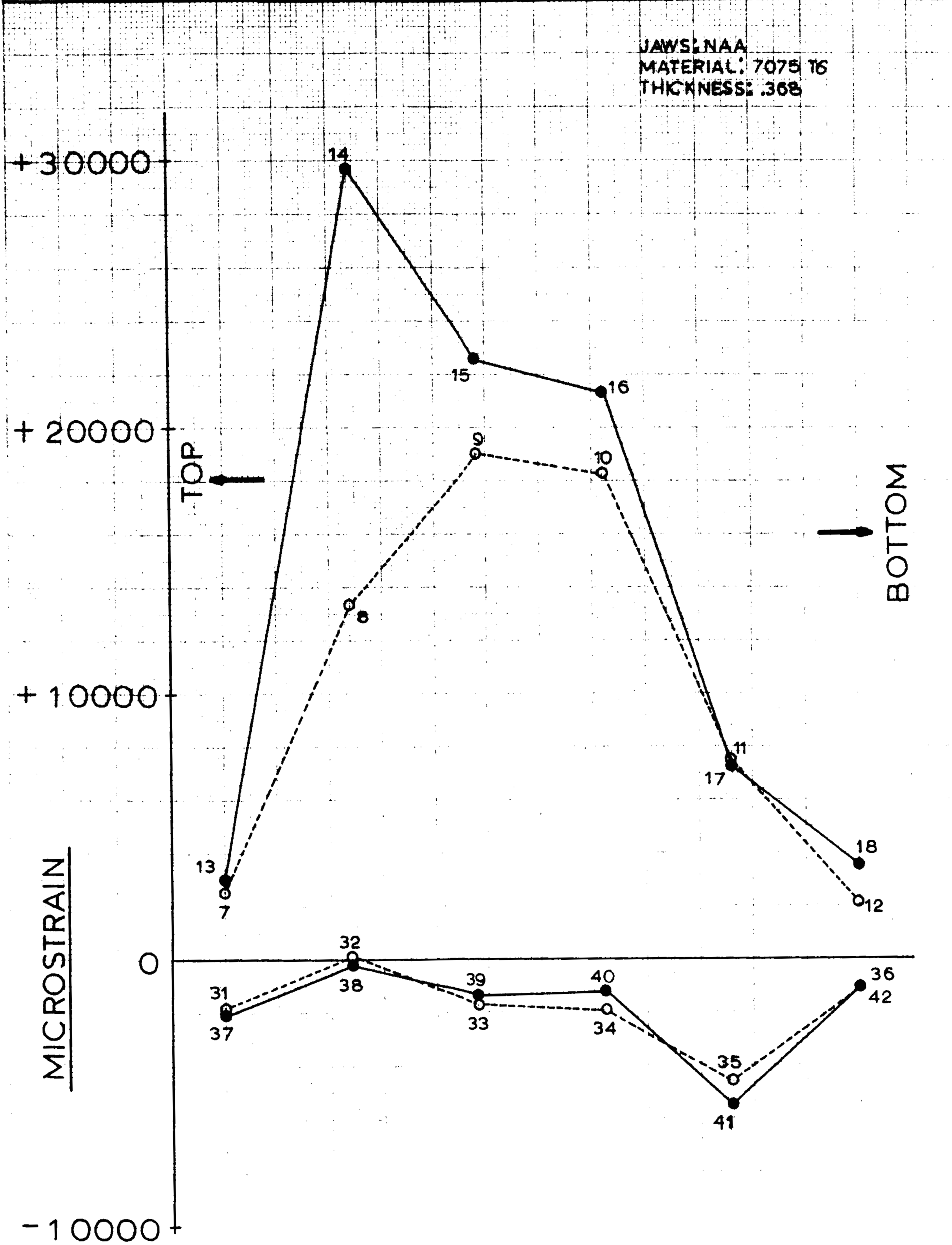
NOTE: STRAIN GAGE LOCATIONS NUMBERED (1) THRU (6), (19) THRU (30), AND (43) THRU (48) AS SHOWN HAVE STRAIN GAGES ON THE REVERSE SIDE OF THE PANEL ALSO AND THE GAGES ARE NUMBERED ONE HUNDRED NUMBERS HIGHER THAN THOSE ON THE FRONT SIDE. EXAMPLE: (1) ON THE FRONT AND (101) ON THE BACK SIDE.

47-2

FORM 113-N-2

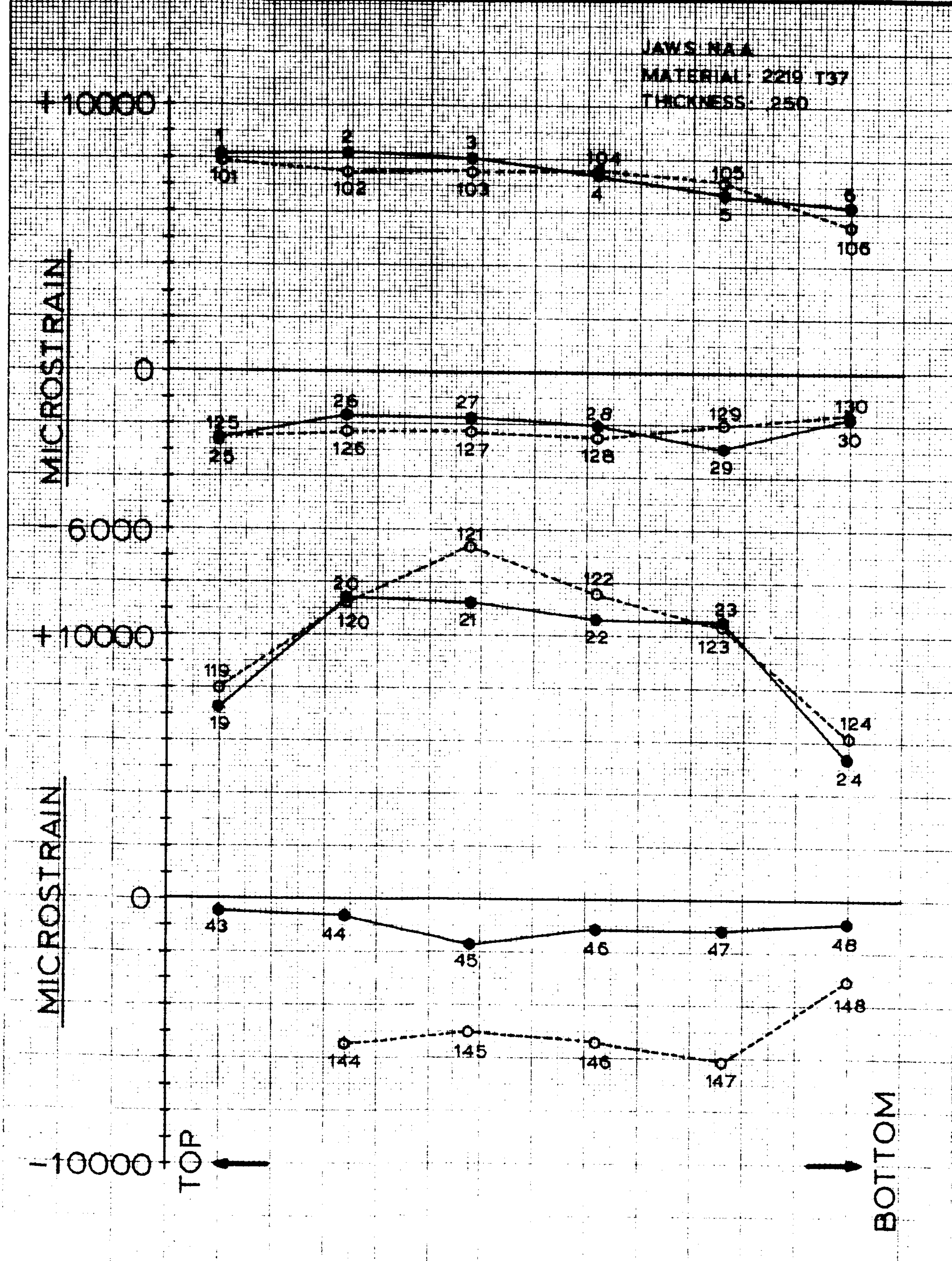
PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 48 OF 63
CHECKED BY:	Figure No. 37	REPORT NO.
DATE:	NAA 3 PANEL	MODEL NO.





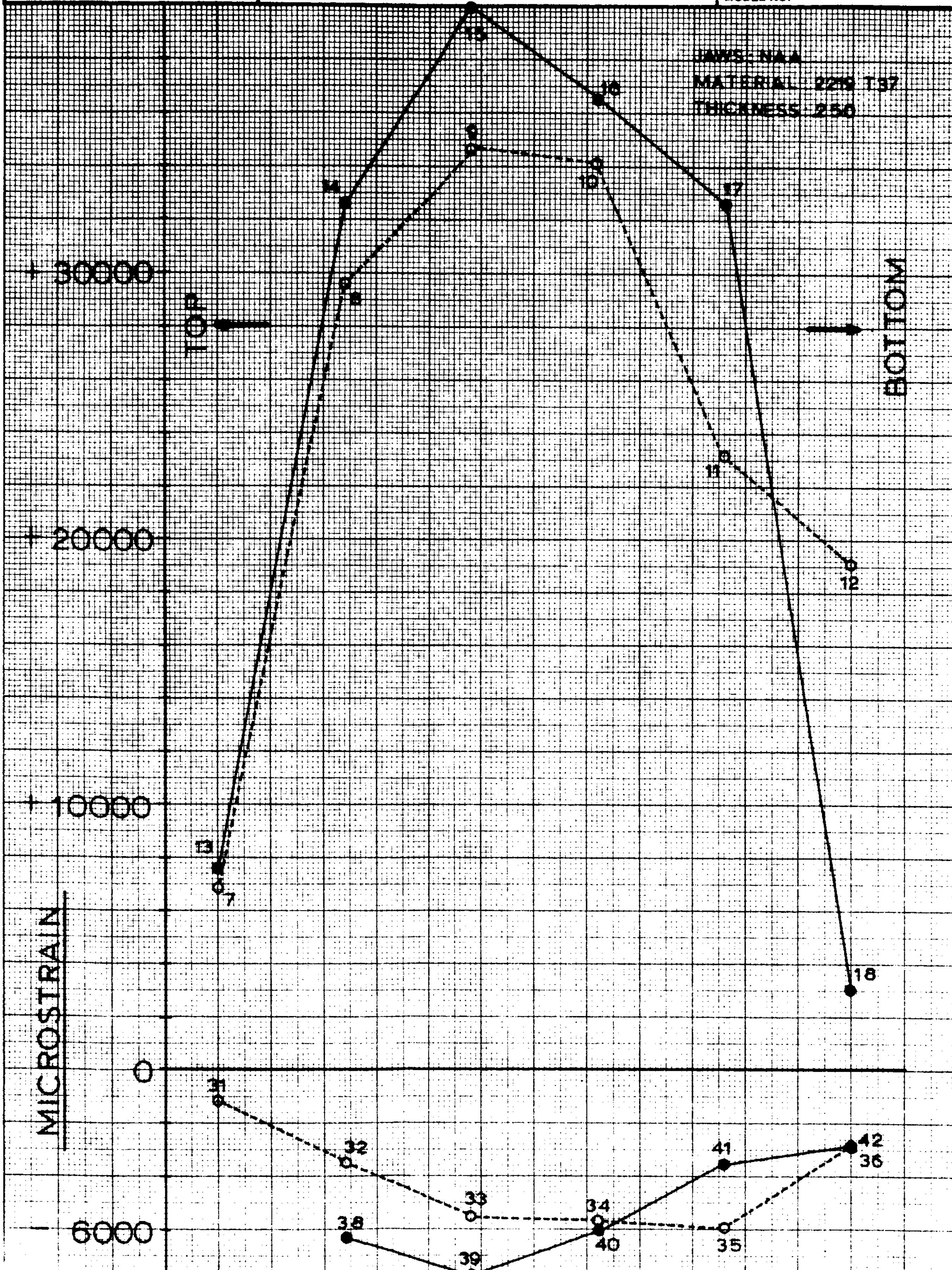
JAWS: NAA
MATERIAL: 7075 T6
THICKNESS: .368
+30000
+20000
+10000
0
-10000
MICROSTRAIN
TOP
BOTTOM
14
15
16
13
7
8
9
10
11
17
18
12
31
37
32
38
39
33
40
34
35
41
36
42

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 50 OF 63
CHECKED BY:	Figure No. 39	REPORT NO.
DATE:	NASA 1 PANEL	MODEL NO.



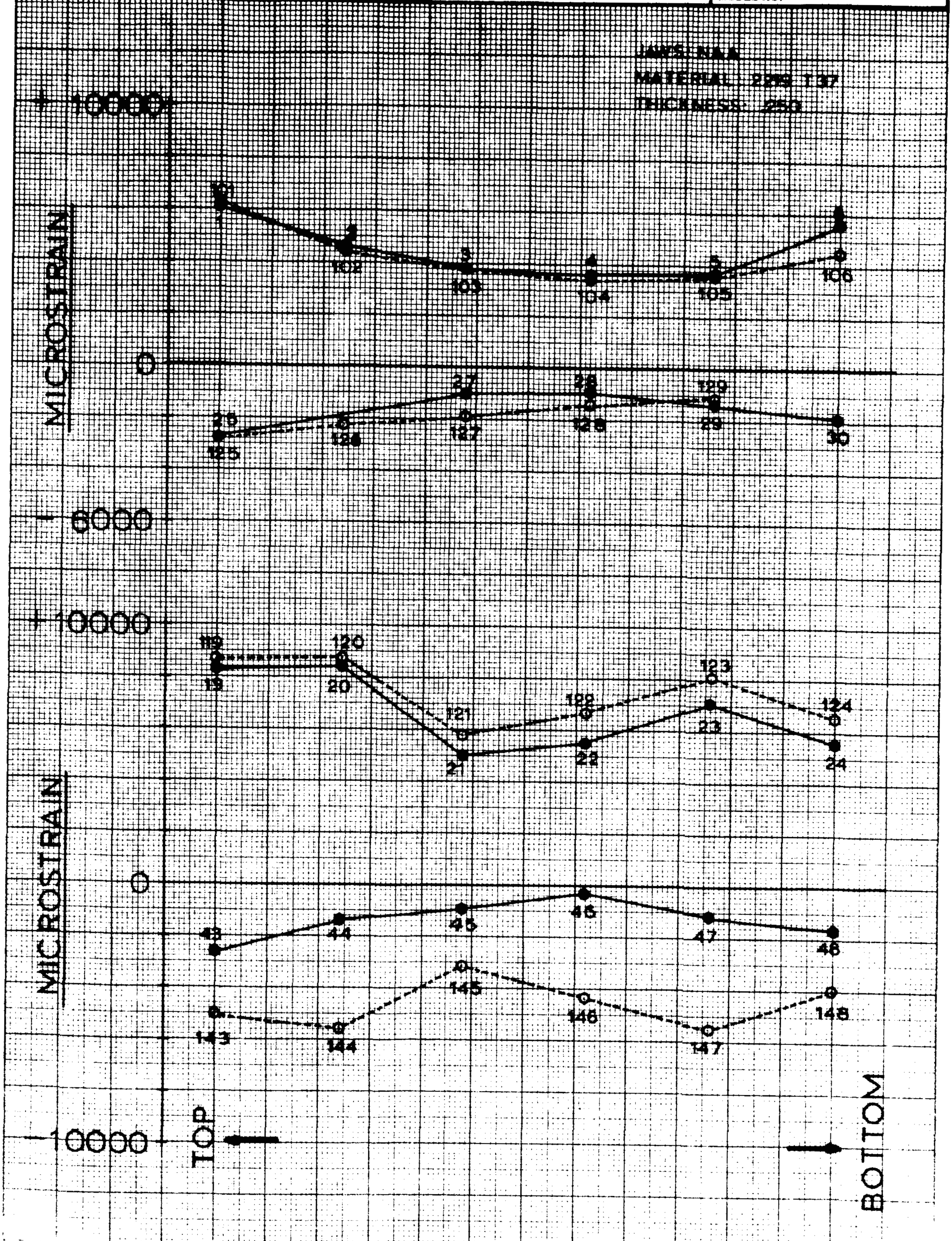
FORM 113-H-2

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 51 OF 63
CHECKED BY:	Figure No. 40	REPORT NO.
DATE:	NASA 1 PANEL	MODEL NO.



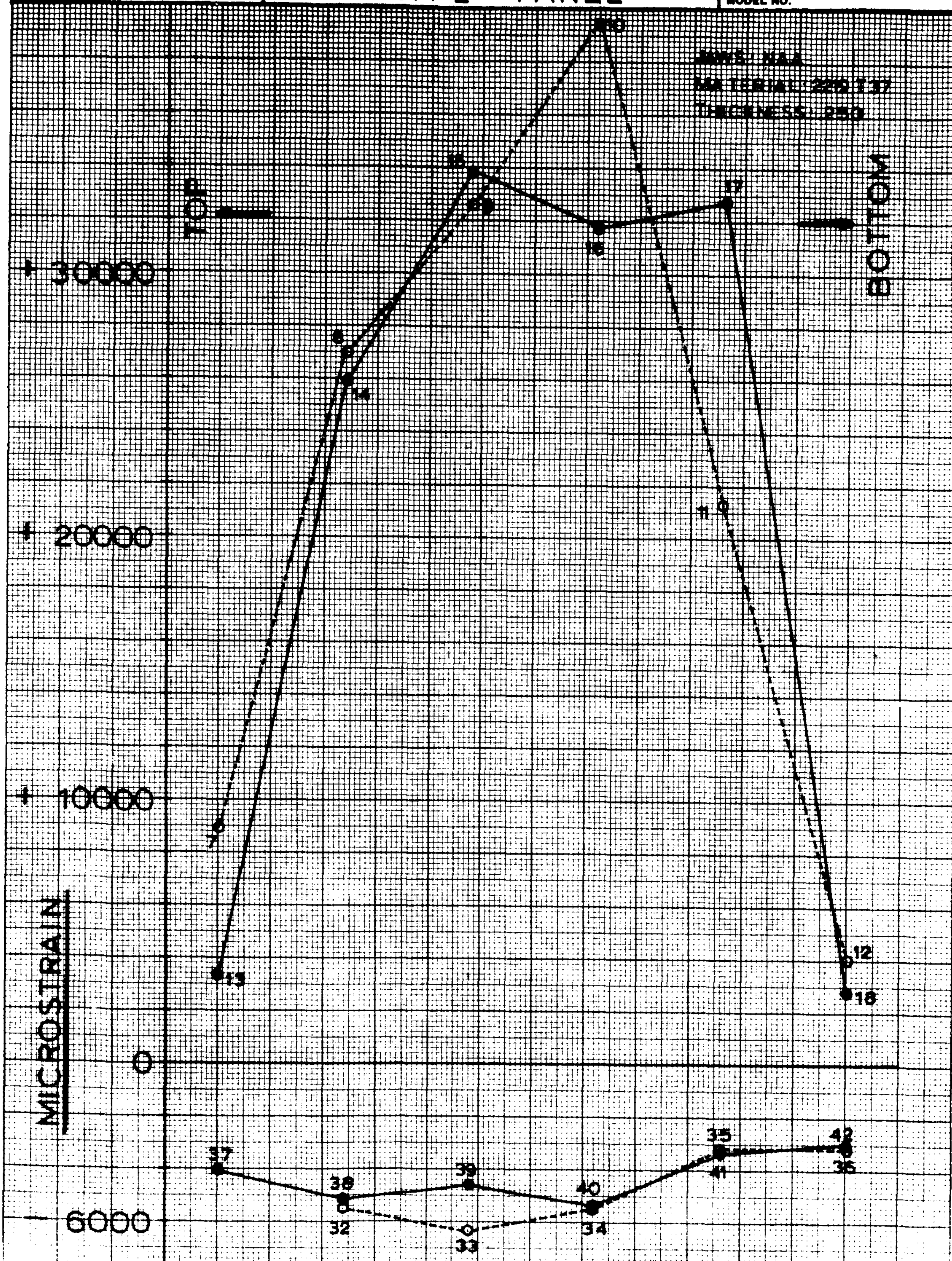
FORM 110-R-8

PREPARED BY:	**NORTH AMERICAN AVIATION, INC.**	PAGE NO. 52 OF 63
CHECKED BY:	Figure No. 41	REPORT NO.
DATE:	NASA 2 PANEL	MODEL NO.



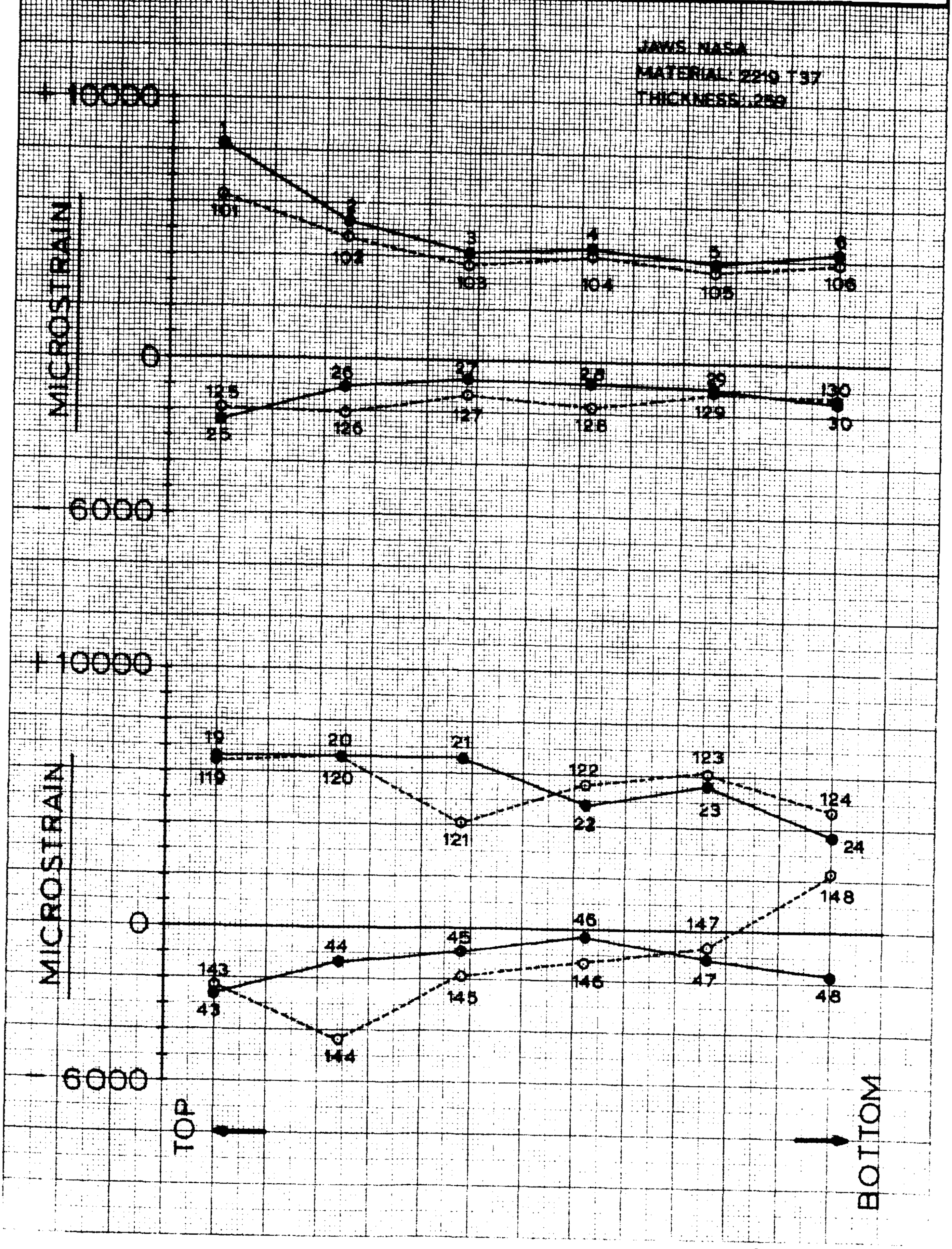
FORM 115-H-2

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 53 OF 63
CHECKED BY:	Figure No. 42	REPORT NO.
DATE:	NASA 2 PANEL	MODEL NO.



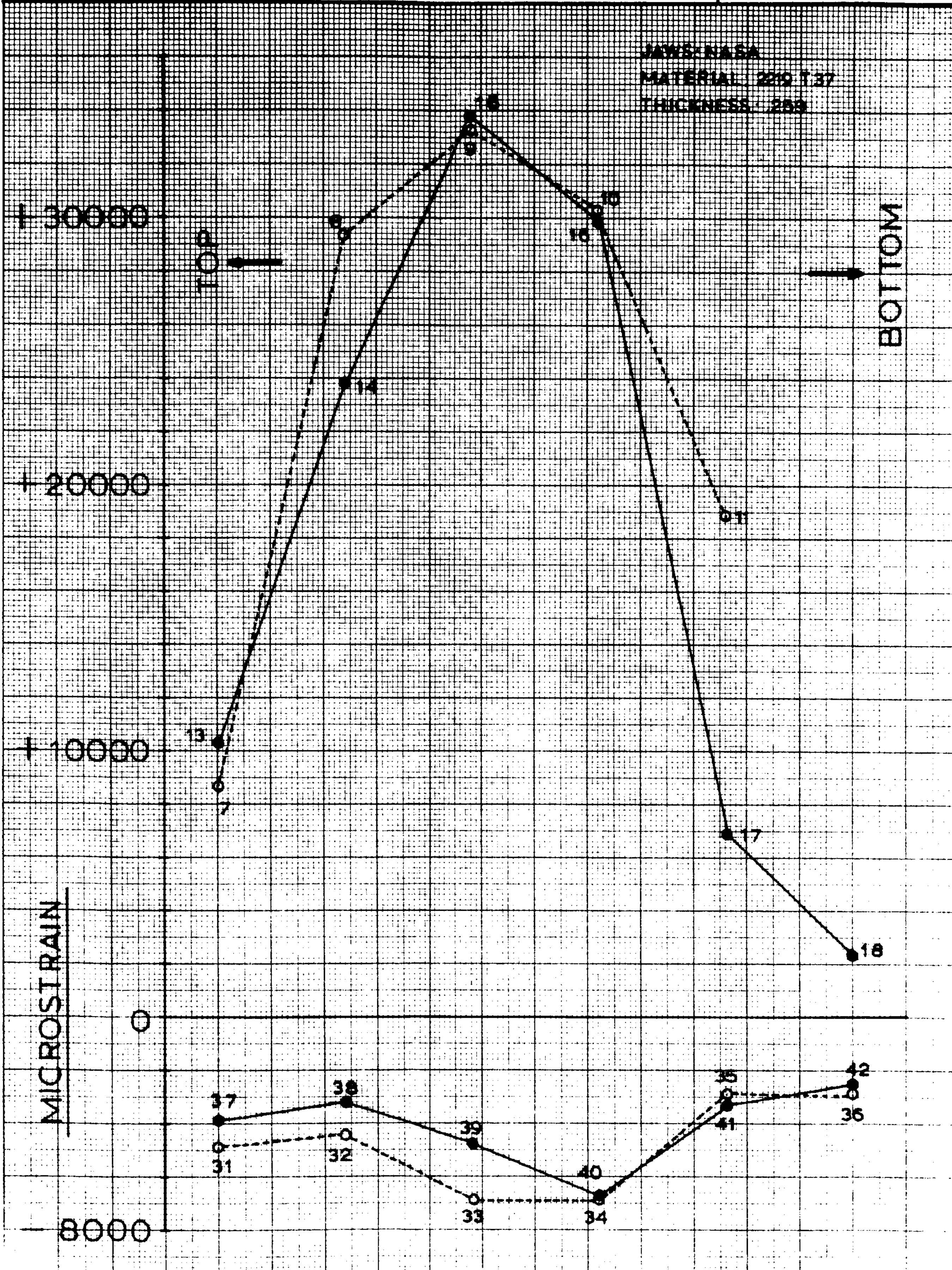
FORM 115-H-2

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 54 OF 63
CHECKED BY:	Figure No. 43	REPORT NO.
DATE:	NASA 3 PANEL	MODEL NO.



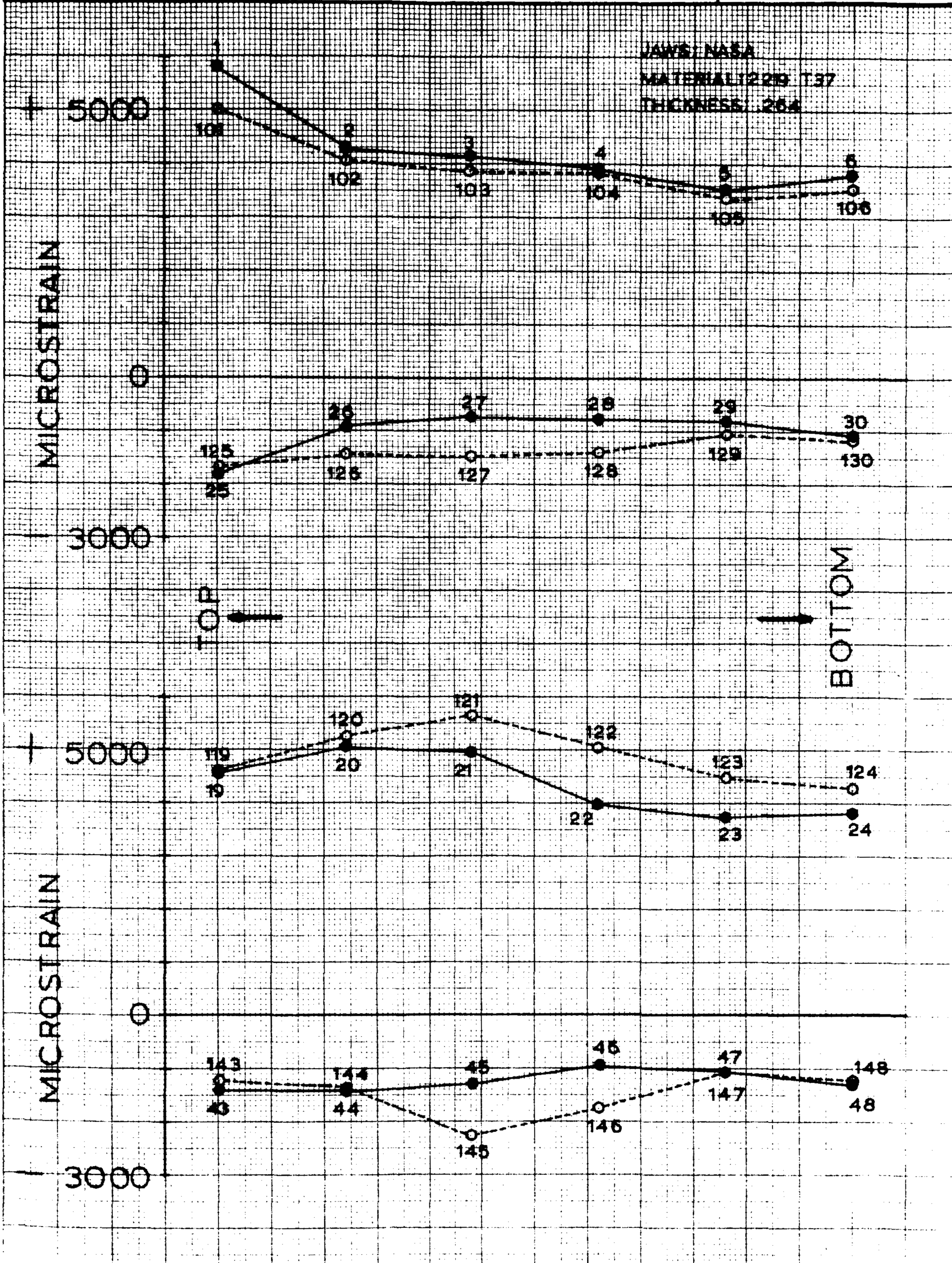
FORM 113-N-2

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 55 OF 63
CHECKED BY:	Figure No. 44	REPORT NO.
DATE:	NASA 3 PANEL	MODEL NO.



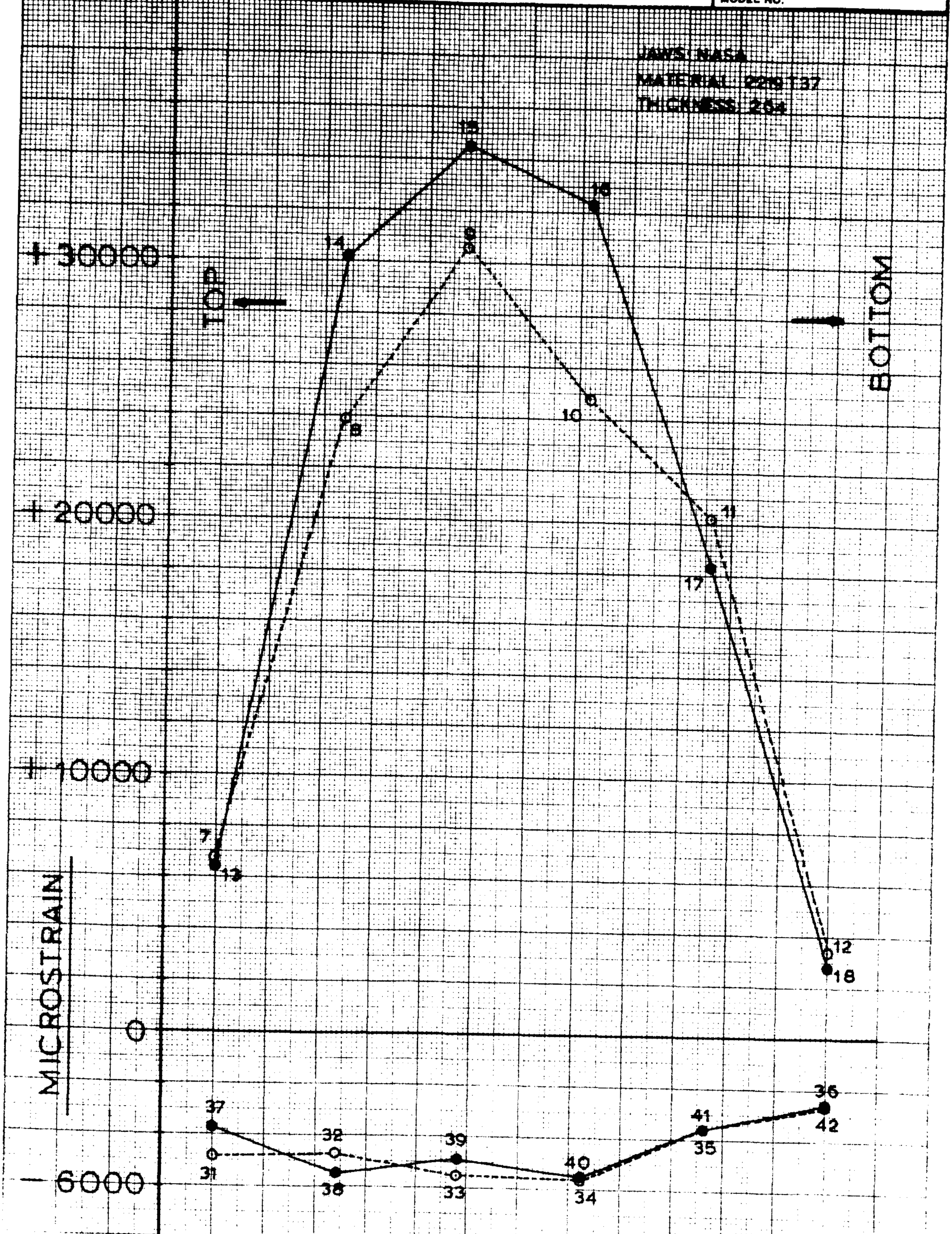
FORM 110-H-2

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 56 OF 63
CHECKED BY:	Figure No. 45	REPORT NO.
DATE:	NASA 4-1 PANEL	MODEL NO.



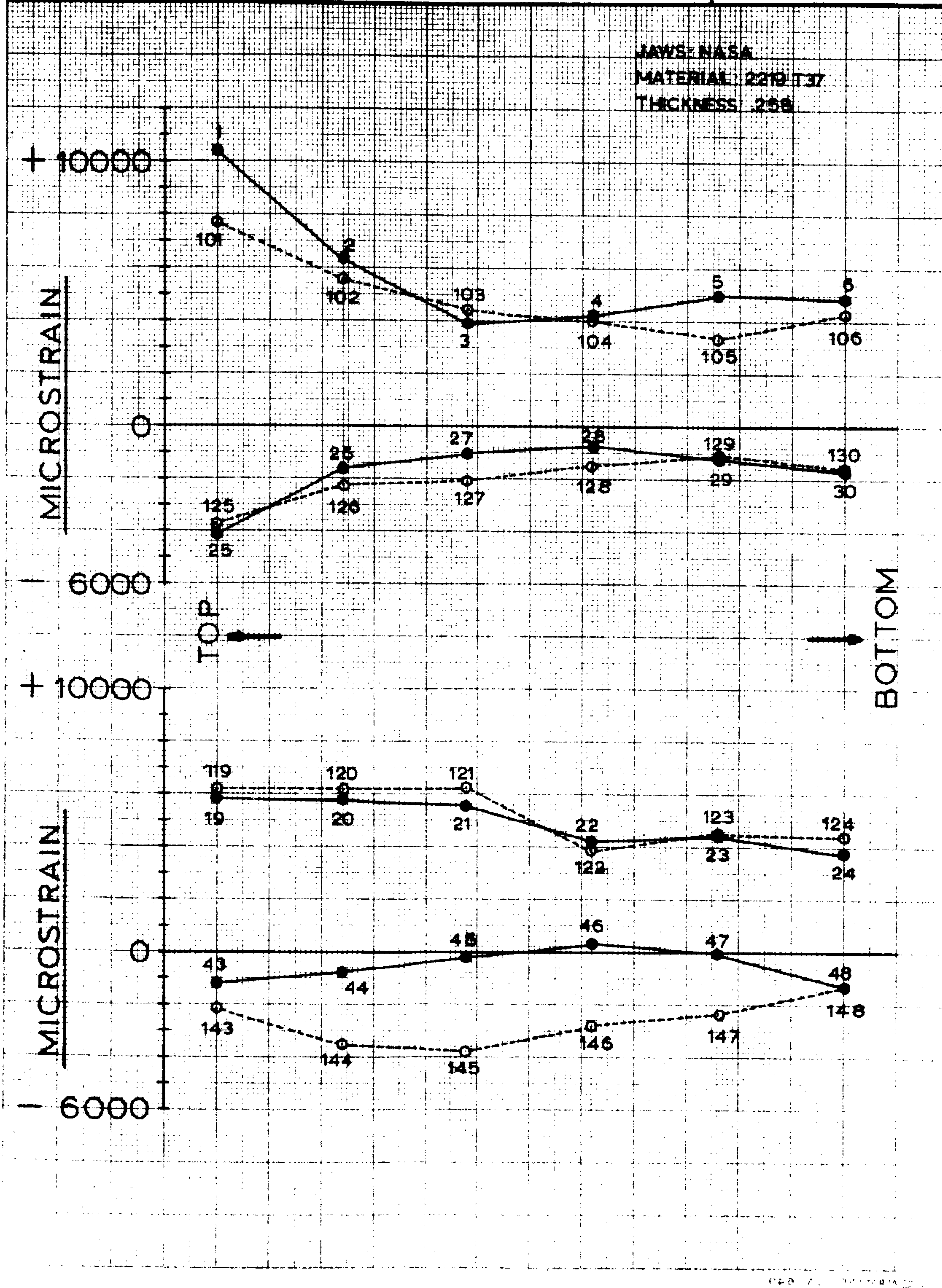
FORM 113-N-2

PREPARED BY:	**NORTH AMERICAN AVIATION, INC.**	PAGE NO. 57 OF 63
CHECKED BY:	Figure No. 46	REPORT NO.
DATE:	NASA 4-1 PANEL	MODEL NO.



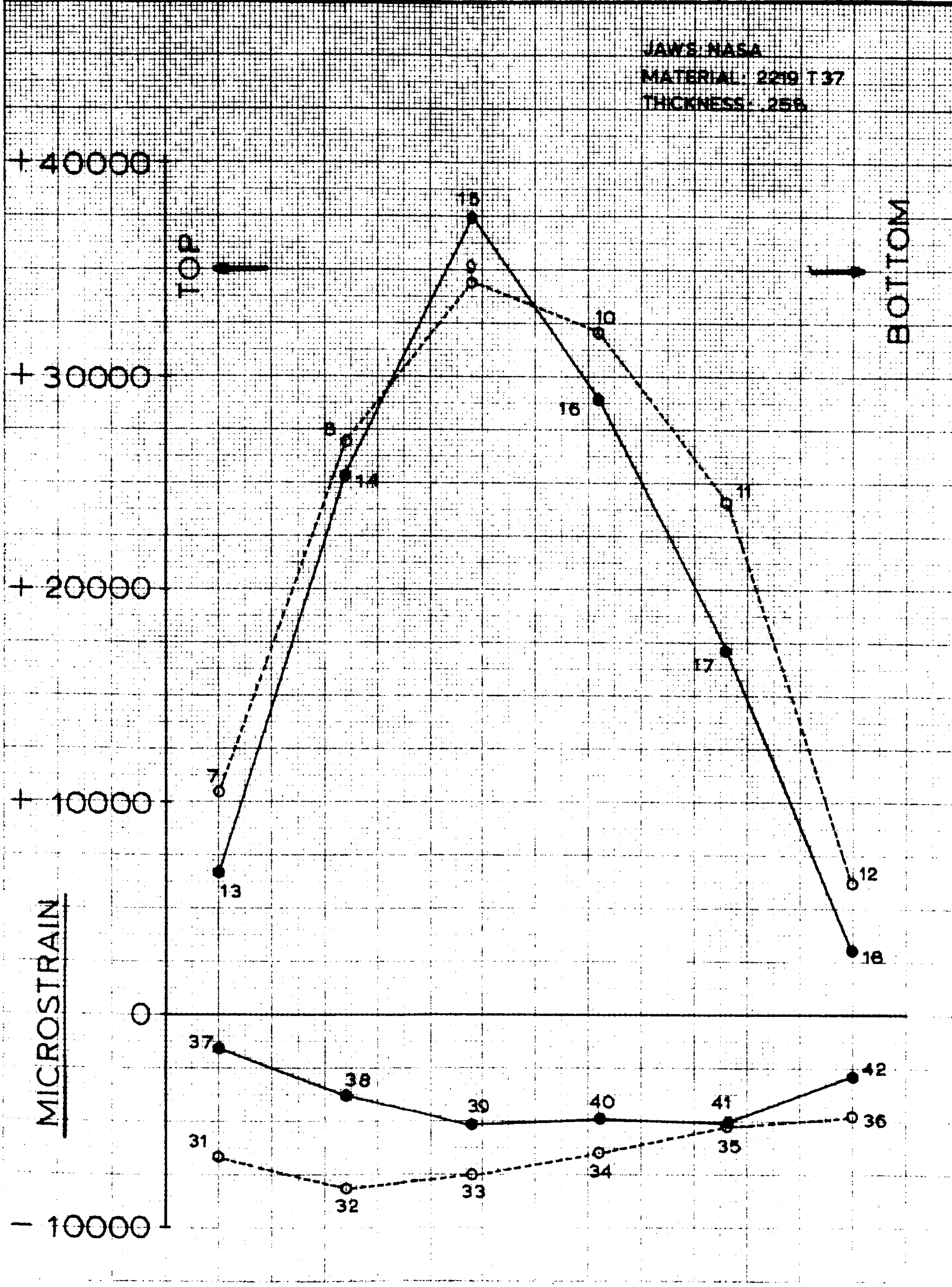
FORM 115-N-2

	NORTH AMERICAN AVIATION, INC.	
PREPARED BY:		PAGE NO. 58 OF 63
CHECKED BY:	Figure No. 47	REPORT NO.
DATE:	NASA 4-2 PANEL	MODEL NO.



FORM 113-N-8

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 59 OF 63
CHECKED BY:	Figure No. 48	REPORT NO.
DATE:	NASA 4-2 PANEL	MODEL NO.



FORM 112-N-2

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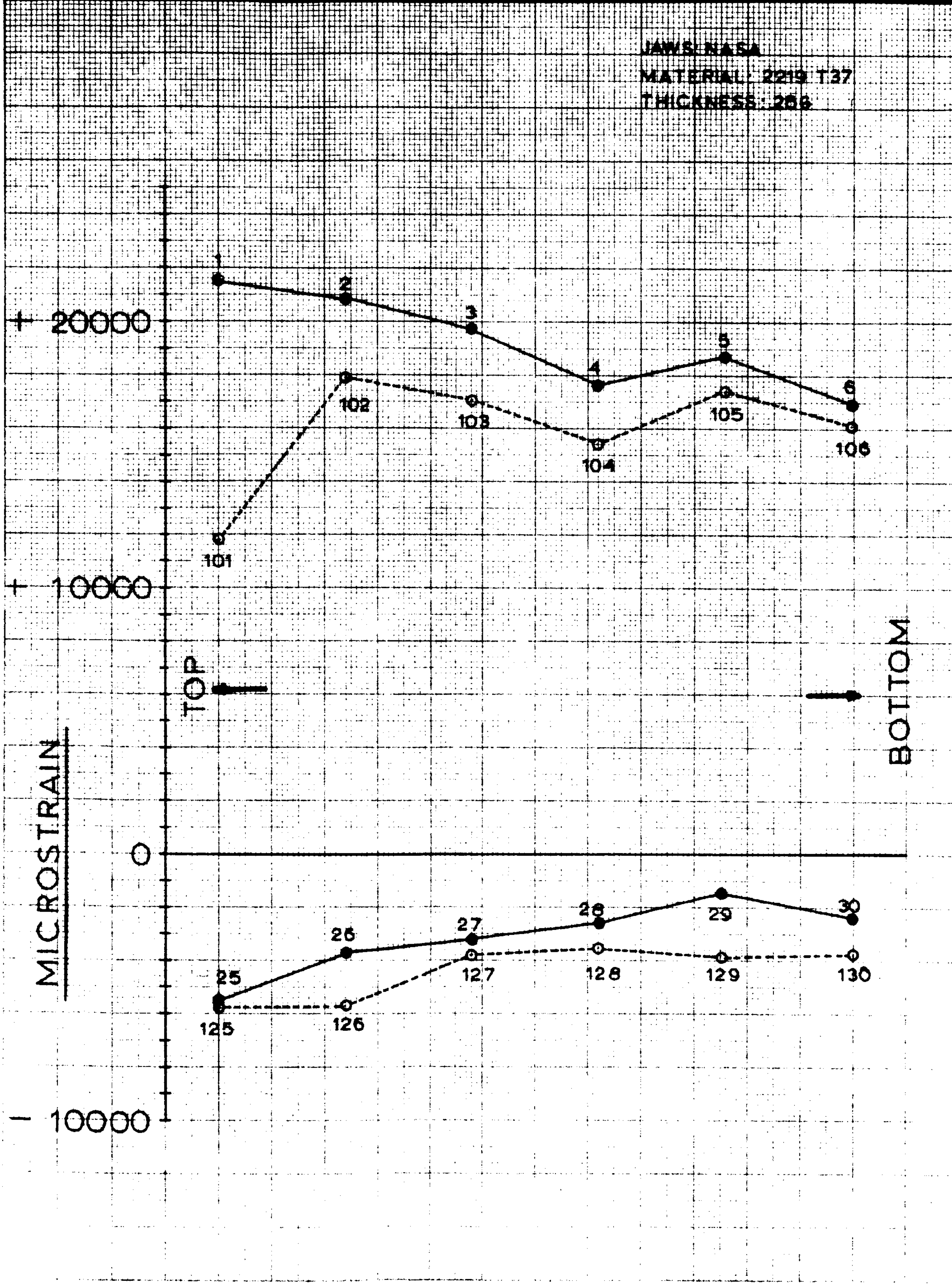
CHECKED BY:	Figure No. 49	REPORT NO.
DATE:	NASA 4-3 PANEL	MODEL NO.



FORM 113-N-6

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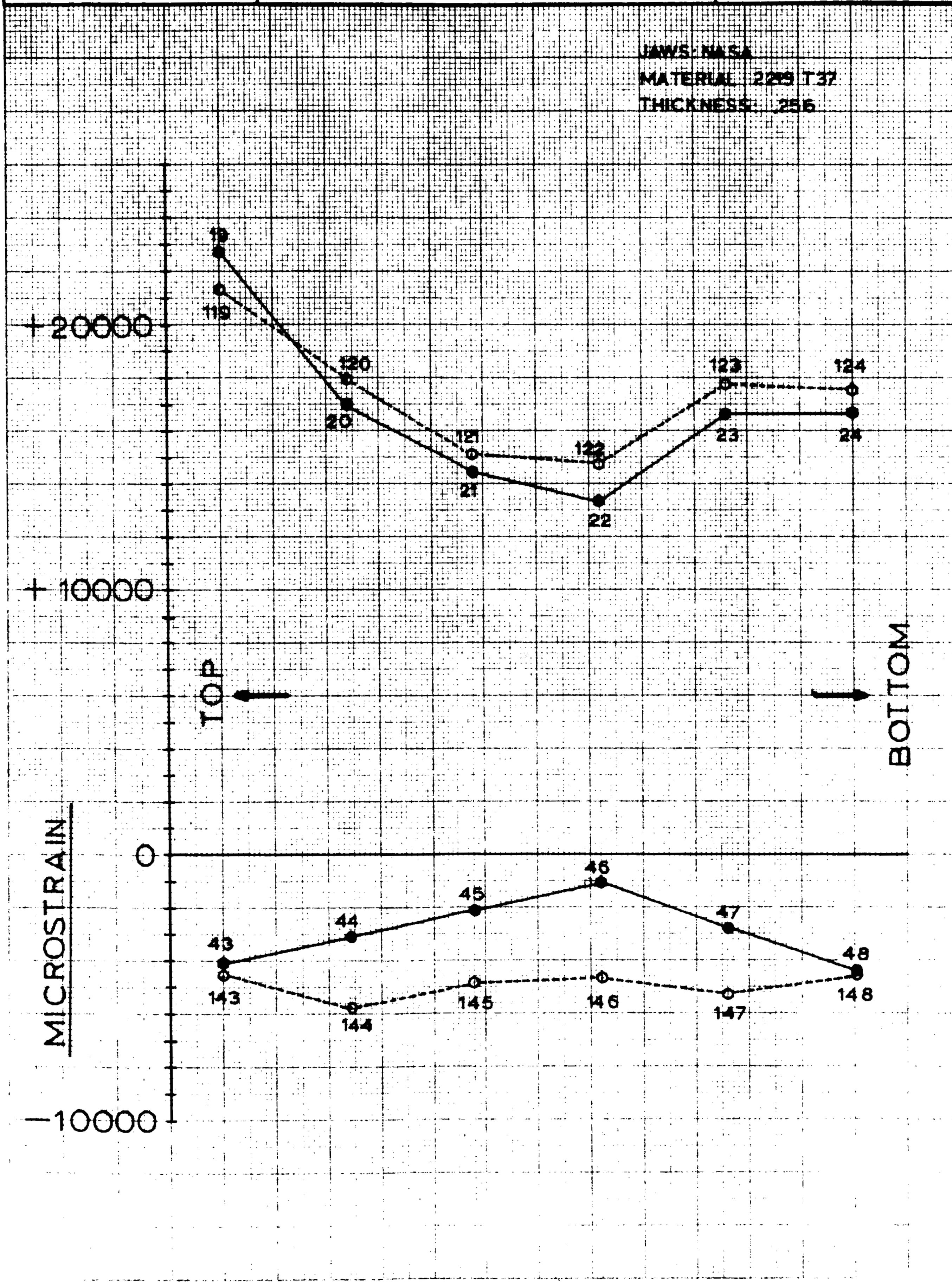
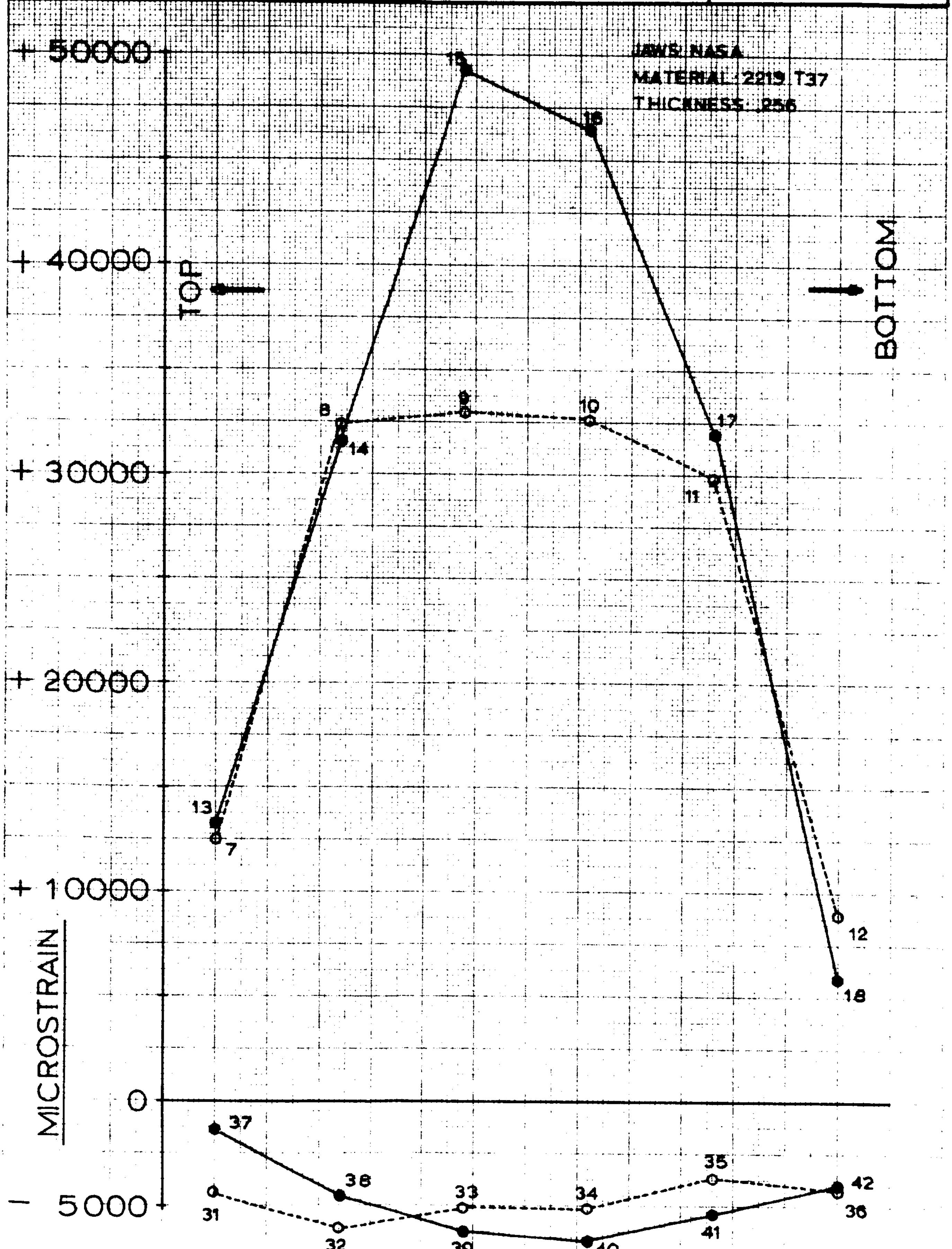
CHECKED BY:	Figure No. 50	REPORT NO.
DATE:	NASA 4-3 PANEL	MODEL NO.



FORM 113-N-8

PREPARED BY:	NORTH AMERICAN AVIATION, INC.	PAGE NO. 62 OF 63
CHECKED BY:	Figure No. 51	REPORT NO.
DATE:	NASA 4-3 PANEL	MODEL NO.



IV - ACKNOWLEDGEMENTS

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