

MS-I

AGE FORMING of CENTER PIECE HEAD S-1C

By Robert W. Lightstone

Final Report

January 1965

GPO PRICE \$ _____

OTS PRICE(S) \$ _____

Hard copy (HC) 2.00

Microfiche (MF) 50

Prepared Under Contract No. NAS 8-11717 by

THE BOEING COMPANY

Wichita Branch

Wichita, Kansas 67210

N65 18913

(ACCESSION NUMBER)

(THRU)

(PAGES)

(CODE)

(NASA CR OR TMX OR AD NUMBER)

(CATEGORY)

Prepared for:

George C. Marshall Space Flight Center
National Aeronautics & Space Administration
Huntsville, Alabama 35812

FACILITY FORM 803

REV SYM:

E-3033

3
BOEING

NO. NAS 8-11717

SECT

PAGE

1

Final Report

NAS 8-11717

<u>Table of Contents</u>	<u>Page</u>
SUMMARY OR ABSTRACT	1
LIST OF APPENDIX ITEMS AND FIGURES	2
FOREWORD	3
SCOPE OF WORK	4
WORK PERFORMED	5-7
Introduction	5
Test Program	5
Test Parts and Tooling Configuration	6
Test Procedure	7
EVALUATION OF RESULTS	8-11
Material	8
General Considerations	8-11
Conclusions	11
Recommendations	11
APPENDIX AND FIGURES	

REV SYM:

E-3033

BOEING	NO. NAS 8-11717
SECT	PAGE 11
Final Report	

SUMMARY OR ABSTRACT

18913
The primary objective of this investigation was to determine the capabilities of age forming 2219-T37 aluminum to a compound curved form in the configuration as represented by the Saturn S-1C Bulkhead Center Piece. The geometric shape of the part is a segment of an ellipsoidal shell.

The fact that the shell segment was located at the Y axis pole and of very small curvature compared to the full ellipsoid permitted substitution of a spherical form as the test configuration.

A fixture was designed and fabricated with interchangeable die and punch inserts so that variables of thickness and depth of curvature could be investigated, using one aging fixture. Age formed test parts were measured to establish amount of curvature retention, effect of grain direction, and growth of the alloy.

The data was analyzed and evaluated to obtain practical parameters which were used to design and fabricate tooling to age form sculptured blanks having a predetermined form after age forming.

Four important conclusions were obtained:

1. The age forming of compound contoured configuration proved feasible and repetitive for consistent manufacturing capability. Three sculptured centerpieces were age formed within tolerances set forth in MSFC Dwg. MR&T-SK-714.
2. The percent of retention varies with thickness.
3. The percent of retention is greater in the longitudinal grain direction than in the transverse grain direction and varies at the same rate with respect to material thickness.
4. Material growth occurs in all directions and varies to a limited extent with grain direction and thickness.

Author

REV SYM:

E-3033

BOEING	NO. NAS 8-11717
SECT	PAGE 1
Final Report	

LIST OF APPENDIX ITEMS AND FIGURES

Appendix

A	Empirical Method for Symmetrical Overform
B	Comparison of $\frac{x^2 + 2y^2}{198^2} = 1$ with $\frac{x^2 + y^2}{279.238^2} = 1$
C	Mechanical Properties Report 2219-T37
D	Mechanical Properties Report 2219-T87
E	Stress Calculations on MIT-RSC-MR&T-SK-714
F	Data Sheet - Summation of Work Sheets

Figure

1	MSFC Drawing MR&T-SK-714
2	Sketch of Scribe Lines for Test Parts
3	Graph of Ratio R_f to R_p
4	Graph Showing Lineal Growth in Age Forming
5	MR&T-SK-714 Center Piece Blank - Adjusted for Material Growth
6	MR&T-SK-714 Part No. 1 Material Growth
7	MR&T-SK-714 Part No. 2 Material Growth
8	MR&T-SK-714 Part No. 3 Material Growth
9	Deviation from 279.3" R MR&T-SK-714, Part No. 1
10	Deviation from 279.3" R MR&T-SK-714, Part No. 2
11	Deviation from 279.3" R MR&T-SK-714, Part No. 3
12	MIT-RSC-MR&T-SK-714 Age Forming Fixture
13	Measurement with Part Supported on Flat Surface
14	Curvature Measurement with Blank Supported on Rubber Pad at Center of Concave Side
15	R&D Master in Open Fixture for Forming to 181" Radius Die
16	Sculptured MR&T-SK-714 Center Piece Without 8" Diam. Center Hole - Prior to Age Forming
17	Sculptured MR&T-SK-714 Center Piece with 8" Diam. Cutout - Prior to Age Forming
18	R&D Master Reinforced to Hold Developed Configuration During Plaster Casting
19	Plaster Die Pattern & R&D Master Ready for Casting of Plaster Punch Pattern
20	Plaster Punch Pattern
21	Plaster Die Pattern
22	Completed Part Contour Compared to 279.3" Radius Template
23	Age Formed MR&T-SK-714 Part Nos. 1, 2, 3

REV SYM:

E-3033

FOREWORD

This final technical report covers the work performed from June 26, 1965, through December 22, 1964, under George C. Marshall Space Flight Center Contract NAS 8-11717 dated June 25, 1964.

This contract was conducted by The Boeing Company, Airplane Division - Wichita Branch. The work was performed under the direction of Virgil Gerstner (Manager) and R. E. Layton (Unit Chief, Tooling-Metalworking-Metallurgy) Manufacturing Development Section, by Robert W. Lightstone, Project Engineer.

The contract was initiated by Program R&D Branch of Marshall Space Flight Center and was administered by C. H. Maroney, Technical Representative, and L. A. Bowers, Alternate, Industrial Support Branch, Manufacturing Engineering Laboratory.

REV SYM:

E-3033

BOEING	NO. NAS 8-11717
SECT Final Report	PAGE 3

SCOPE OF WORK

Contract NAS 8-11717 was initiated to determine the feasibility of age forming double contoured parts to a configuration as represented by the S-1C Bulkhead Center Piece as shown on MSFC Sketch MR&T-SK-714 dated March 27, 1964, and revised July 30, 1964, Appendix Figure 1, and to resolve problems associated with this operation.

The work included design and fabrication of a tool in which 2219 aluminum alloy in T37 condition could be age formed to the T87 condition. The tool was to be of sufficient strength and durability to hold the blanks to a predetermined shape during the aging process and to accommodate thermal expansion and expected material growth. The one tooling fixture was to be suitable for age forming parts of various constant thickness in two different contours and also to age form the MR&T-SK-714 sculptured parts by the use of removable die and punch holding inserts.

The scope of the work covered forming of 2219-T37 aluminum alloy blanks of a 55" diameter in constant thickness of .250", .500", and .900" to a basic contour of $\frac{x^2 + 2y^2}{198^2} = 1$ and in the same thicknesses to a .650" symmetrical overform of the basic equation. Three test parts of each thickness and of each contour were to be age formed. Three parts, from presculptured blanks per MSFC Sketch MR&T-SK-714, were to be age formed in a holding die and punch adjusted to compensate for parameter variables determined from test forming as follows:

1. The effect of blank thickness on the formed part.
2. The relationship of depth of forming to final contour of the part.
3. The effect of sculptured pattern on the contour.
4. The effect of direction of rolling of blank on final contour.

REV SYM:

8-3033

WORK PERFORMED

Introduction

The Boeing Company - Wichita Branch developed the original technique for age forming contours into single curvature circumferential radii type configurations. This "age forming" process has the unique capability of forming age hardenable alloys without working in the plastic range or exceeding the yield point of the material.

The parameters for manufacturing of single curve configurations have been well established and are being used in production. However, preliminary research has indicated that in the age forming of compound contoured parts the grain direction as produced by the rolling process used in sheet and plate manufacture would produce variations in curvature directly related to the grain direction.

The effort under this contract was to determine the feasibility of age forming compound contours. The approach was to test age form a sufficient number of compound contoured parts to determine and evaluate the characteristics which could be used to establish the compound contour age forming parameters for aluminum alloy 2219-T37.

Test Program

The test program was set up to age form a series of 2219-T37 aluminum panels as follows:

1. Three .250" thick, three .500" thick, and three .900" thick 55" diam. blanks age-formed to a segment of an ellipsoid described by the rotation of an ellipse $\frac{x^2 + 2y^2}{198^2} = 1$ from $X = -27.5$ to $X = 27.5$ about the Y axis.
2. Three .250" thick, three .500" thick, and three .900" thick 55" dia. blanks age formed with a .650" symmetrical overform of the ellipse equation $\frac{x^2 + 2y^2}{198^2} = 1$.
3. Three blanks sculptured to produce a part to conform with the S-1C Center Piece as called for by MSFC Dwg. MR&T-SK-714 (Appendix Fig. 1).

Measurements were made of the age formed constant thickness part to determine the radius of curvature, with and across the grain direction, and material growth resulting from the aging forming process. The measured data was analyzed to set up parameters to be used to compensate for springback and material growth in the age forming of the sculptured parts.

Test Parts and Tooling Configuration

The constant thickness test blanks were machined both sides to the required thickness and were cut to a diameter of 55.099" $\pm .125/-0.000$ inches. Light scribe lines were made on one surface, consisting of four diametrical lines, indexed to the grain direction, and five concentric circles were scribed with 5-inch to 25-inch radii in 5-inch increments and one circle with a radius of 27.549 inches. (See Appendix Figure 2). This gridding was used to locate measuring points. The blanks were age formed so that the grid appeared on the convex surface of the part.

Mechanical properties of the test part material in T37 condition were determined by laboratory tests on sample coupons from part trim. Test coupons were cut from one constant thickness part in each thickness after the age forming process to provide mechanical property data for the T87 condition. Results of these tests are found in Appendices C and D.

The aging fixture MIT-RSC-MR&T-SK-714 was designed in a two-piece octagonal box shape with radial internal reinforced structure. Each sectionpiece supported a removable die or punch insert. Eight slotted latches were used to lock the fixture under pressure during the aging process (Appendix Figure 12). The structure was stress calculated for a closing and holding load of 152,000 lb. (Appendix E).

Welded 6061-T6 aluminum was used throughout the structure in order to maintain equal thermal expansion rates in the fixture and the test parts. The die and punch inserts used with the sculptured parts were fabricated from kirkite in order to permit an economy in the technique used to obtain the desired punch and die configuration. Production inserts of cast aluminum are equally feasible.

The die and punches used to hold the constant thickness test parts were shaped to conform in cross-section to the section of a circle with the equation of $\frac{x^2 + y^2}{279.283^2} = 1$. This configuration does not vary from the ellipse equation $\frac{x^2 + 2y^2}{198^2} = 1$ more than .002 inch over the interval of $X = -27.5$ to $X = 27.5$ and permitted conventional machining operations (Appendix B).

The .650" symmetrical overform was established by adding a percentage of the total overform to the vertical distance from a horizontal line, through the pole of the arc, to any point on the arc at the same rate as the ratio as this distance was to the total chord height (Appendix A).

Test Procedure

The test parts were age formed by placing the flat blanks between the punch and die inserts and closing the fixture in a hydraulic press. The fixture was then locked in a closed position by driving wedges in the slotted latches while under pressure of 152,000 lb. The aging fixture was then transferred to a heat treating oven where the test part was aged for twenty-four hours at a temperature of 325°F. $\pm 10^\circ\text{F}$. This heat treating process transformed the aluminum part from 2219-T37 to a T87 condition. The furnace used for the aging process was a conventional furnace which is certified for temperature uniformity, etc., per established quality control procedures. Certification data is on file in the Quality Control Department of Boeing-Wichita.

After cooling to a maximum of 125°F. the part was removed from the fixture and the chord height at 1" intervals of the chord length were measured along each of the diametrical scribed lines. The increase in surface length over the diametrical length of each concentric scribed circle was measured to determine material growth. Material thickness growth measurements were made on selected test parts in each thickness.

The measurements of the test parts were made with the part supported on a 10" diameter rubber disc at the center of the concave side. This method gave a near free standing part and eliminated distortion induced by the part weight and irregularities when supported on the edge, or in a fixture (Appendix Figures 13 & 14). Material growth was measured by a scale with .010" divisions and estimated to the nearest .005". Thickness growth was measured by micrometer and by Vidigaging.

Test Part No. 6 was age formed with an eight-inch diameter center cut-out in order to observe the effect on growth and springback. One test part in each thickness and each fixture curvature was subjected to closing and then opening of the fixture after which it was measured to determine presence of any permanent set. No permanent deformation was incurred in any of the test parts.

Two of the sculptured parts MR&T-SK-714 Nos. 1 & 2 were age formed without the center 8" dia. hole to permit observation of consistency with constant thickness parts (Figures 16 and 17). Part MR&T-SK-714 No. 3 was age-formed with the 8" dia. center hole. Also an 8" diameter hole was machined in the MR&T-SK-714 No. 1 part after age forming and measuring to determine effects of the center cut-out.

REV SYM:

E-3033

EVALUATION OF RESULTS

Material

Aluminum Alloy 2219 in T37 condition was the material used for the test blanks. The age forming operation of heat treating at 325°F. for a period of 24 hours produced the T87 condition in the age formed part. Analysis of the mechanical properties of the material used in this investigation is shown by Appendices C and D.

A comparison with the standard minimum average tensile yield and ultimate strength reveals that age forming produces no detrimental effects on the material strength, in fact there is an indication of a slight increase in mechanical properties.

General Considerations

The most important parameter effecting the ability to age form to a required configuration is the amount of overform that will be required in the aging fixture to overcome the inability of the material to retain the full configuration of the fixture. The segment of an approximate spherical shell shape of the S-1C polar cap places the spherical radii as the basic measurement for data accumulation and evaluation. The data assembled from work sheets (Appendix F) showed that in the compound contour of the test shape, the retention of radii in the longitudinal grain direction were greater than the retention of radii in the transverse grain direction. The radius of the developed part was calculated by measuring the chord height along lines parallel to the grain and perpendicular to the grain direction and using the equation $R = \frac{4CH^2 + CL^2}{8CH}$ where CH = chord height, CL = chord length, and R = radius. The percent of retention was based on the residual strain in the part as calculated from the equation, percent retention = $\frac{S_p}{S_f} \times 100$, with S = calculated from strain (S) = $\frac{T}{2R}$ where T = thickness and the subscripts 'p' and 'f' represent the developed part and the fixture respectively.

A graph was prepared (Figure 3) using the fixture radius as the ordinate and the developed radius as the abscissa. The average of the radii in the transverse and in the longitudinal grain direction for each material thickness for

REV SYM:

E-3033

BOEING	NO. NAS 8-11717
SECT	PAGE 8
Final Report	

the two fixture radii were used to establish the points on the graph. Several important parameters were shown by the graph. The rate of change in the ratio of the R_p to R_f for longitudinal grain direction decreases slightly as the thickness increases. The rate of change in the transverse grain direction did not vary consistently as the thickness varied; the .250" and .900" thickness rates of change are similar while the value of change of the .500" thickness increases with increase of radius. The surface growth also is found to increase with increase in material thickness (Figure 4). This is understood because of the relationship between S & T in the equation $S = \frac{T}{2R}$. Material thickness also increases during the age forming process. This factor was used to calculate a blank size.

To achieve the final objective of the project, the forming of the sculptured part of various thickness to a spherical shape, corrective measures were required to provide for the material growth and for the difference in the amount of corrective retention in the transverse grain direction and in the longitudinal direction. The growth factor was compensated for by re-dimensioning the part blank as shown in Figure 5.

The adjustment for the differences in percent of curvature retention require a fixture having a surface configuration produced by the trace of an arc rotated about its pole, with the radius cycling from a maximum to a minimum and back to a maximum during 180° of rotation.

Looking toward the production future of age forming as well as the direct fabrication of the MR&T-SK-714 test specimens, alternate methods were considered. A method was sought that could avoid the initial preparations for numerical control machining or could avoid the numerous coordinated template-type hand-formed fixture approach.

A unique and novel method was developed by which the desired configuration could be fabricated using only conventional machines and manufacturing techniques and requiring a nominal manhour expenditure.

REVLTR:

E-3033 R1

This tooling concept was developed as follows:

1. Using the Fixture Radius / Developed Part Radius Graph (Figure 3) it was found that to produce a developed radius of 279.238" (MR&T-SK-714 spherical radius) the fixture would require 238" radius in the part longitudinal direction and 206" radius in the part transverse direction..
2. Using the graph again and using the 238" radius in the transverse direction and 206" R in the longitudinal direction the fixture radius is determined as 181".
3. A die and punch fixture was then machined to the 181" spherical radius and a blank called the R&D Master was age formed (Figure 15). The radii of the R&D Master was 238" and 206" as required and anti-pated (Figure 15).
4. Plaster patterns were made of the convex side and of the concave side of the R&D Master. Grain direction was indexed on the patterns (Figures 18 thru 21).
5. In turn the plaster patterns were used to cast a kirksite die and punch set for the aging fixture. The grain indexing was maintained on the kirksite punch and die set.
6. The MR&T-SK-714 sculptured part was then placed in the aging fixture but with the part grain direction rotated 90° from that of the die and punch. This operation was required to adjust for the grain reversal occurring between Steps 2 and 3 above.
7. Age forming of the part clamped in the fixture produced the required 279.3" spherical radius part within tolerance requirement.

Parts MR&T-SK-714 No. 1 and No. 2 were age formed from sculptured blanks without the 8" diameter center cut-out. Part MR&T-SK-714 No. 3 blank was machined with the 8" dia. cut-out prior to age forming with the exception of the 8" center diameter of the Parts No. 1 & No. 2. All three parts were very close to the required basic contour and all within the .060" deviation allowance. The rate of change did not exceed the .050" in 10" in any part with the exception of a local area within the 8" center area of Parts No. 1 & No. 2 (Appendix Figures 6 thru 11).

There is a slight turn up on the edge of the parts and an underform in the center 8" dia. area on all parts. This condition was expected as the forming parameters were selected on the basis of an average thickness. Complete corrections could have been accomplished by selecting separate radii for each

REV LTR:

E-3033 R1

BOEING		NO. NAS 8-11717	
SECT		PAGE	10
Final Report			

different thickness and machining the punch with the multiple radii configuration.

Conclusions

1. The effect of grain direction and material thickness is consistent and can be predicted from tables established with accuracy sufficient for normal tolerance requirements.
2. The effects of sculpturing in a symmetrical pattern can be predicted and balanced by adjustments in the holding fixture design.
3. The age forming of double contoured configuration in the form of a symmetrical shell segment is feasible and within the normal manufacturing capabilities.
4. By taking advantage of the effects of grain direction upon age formed contours an economical two-stage method of tool fabrication was developed that will reduce production tool and part fabrication costs and use conventional machines (See Page 10).

Recommendations

1. It is recommended that further research be done on compound contoured symmetrical shell configurations. The contours should not be so near spherical but should have a shorter distance between foci and also have greater eccentricity.
2. An investigation to determine the parameters of various age hardenable metal alloys should be conducted in single and compound contoured configurations. Included should be the fusion weldable aluminum alloys 7002, 7039, & X7106.
3. A wider selection of material thickness age formed in a more than one degree of overform should be studied.
4. It is further recommended that the nature of residual stresses in both surfaces of the age formed parts be investigated and compared with similar stresses developed by conventional forming.

Empirical Method for Symetrical Overform

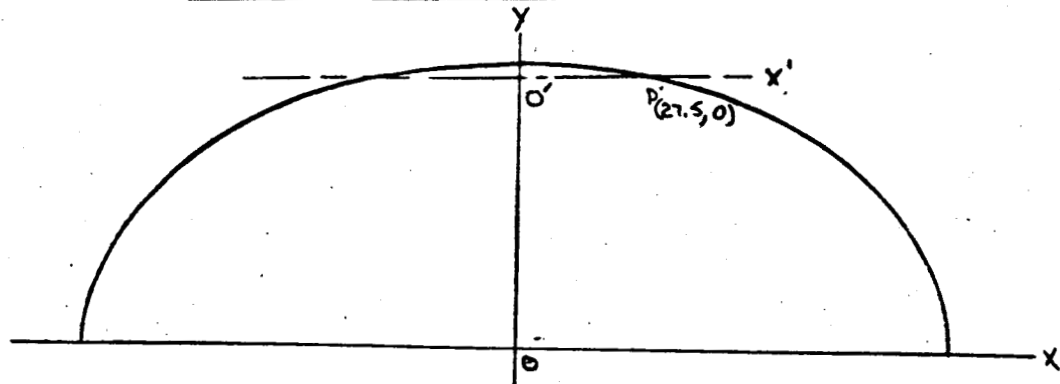


FIG. 1 Translation of Ellipse

$$\frac{x^2 + 2y^2}{198^2}$$

The X Axis of the Ellipse $\frac{x^2 + 2y^2}{198^2} = 1$ is translated to coincide with the Chord of the Curve at X = 27.5

$$\text{At } X = 27.5 \quad Y = \sqrt{\frac{198^2 - 27.5^2}{2}}$$

$$Y = 138.650$$

Translating the Curve Equation becomes

$$Y + 138.650 = \sqrt{\frac{198^2 - x^2}{2}}$$

$$Y = \sqrt{\frac{198^2 - x^2}{2}} - 138.650$$

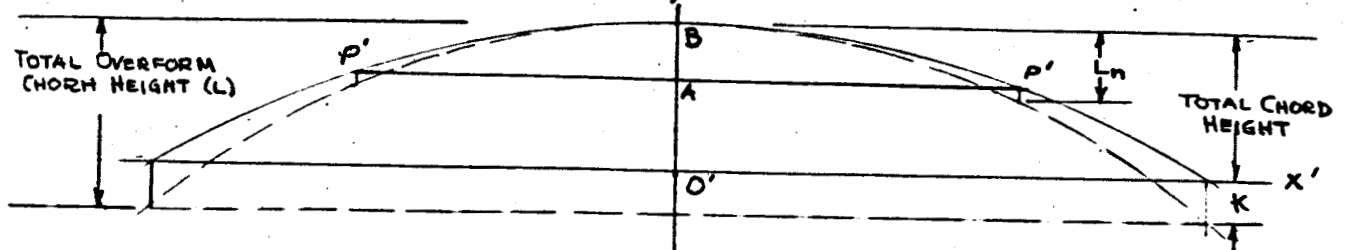


FIG. 2 $Y = \sqrt{\frac{198^2 - x^2}{2}} - 138.650$

BOEING NO. NAS 8-11717

REV SYM:

$$O'B = \text{Total Chord Height } (x=0) = \sqrt{\frac{39204}{2}} - 138.650$$

$$O'B = 1.357 \quad (1)$$

$$\text{For Point P} \quad O'A = \sqrt{\frac{39204 - x_n^2}{2}} - 138.650 \quad (2)$$

$$\text{Chord Height of Chord Thru P} = AB = O'B - O'A.$$

The Empirical Devise for Symmetrical Overform is to Add to the Chord Height (AB) at any Point P the same percent of Maximum Overform K as the percent of the Chord Height (AB) at that point is to the Total Chord Height (O'B).

The Empirical Equation for the above becomes Total Overform Chord Height

$$(\text{At } x_n) \quad L_n = K \left[\frac{O'B - O'A}{O'B} \right] + O'B - O'A$$

Substituting Equations (1), (2)

$$L_n = K \left[\frac{1.357 - \left(\sqrt{\frac{39204 - x_n^2}{2}} - 138.650 \right)}{1.357} \right] + 1.357 - \left(\sqrt{\frac{39204 - x_n^2}{2}} - 138.650 \right)$$

$$L_n = \frac{K}{1.357} \left[1.357 - \left(\sqrt{\frac{39204 - x_n^2}{2}} - 138.650 \right) \right] + 1.357 - \left(\sqrt{\frac{39204 - x_n^2}{2}} - 138.650 \right)$$

$$L_n = \left(\frac{K}{1.357} + 1 \right) \cdot (140.007 - \sqrt{\frac{39204 - x_n^2}{2}})$$

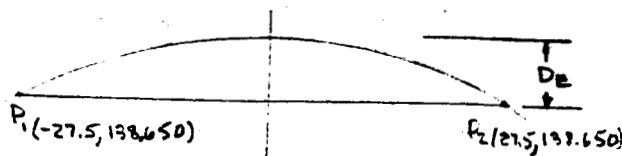
$$\text{For } K = .650 \quad L_n = 1.479 (140.007 - \sqrt{\frac{39204 - x_n^2}{2}})$$

REV SYM:

E-3033

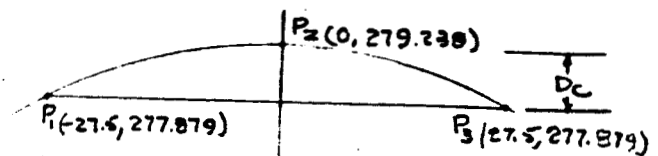
BOEING NO. NAS 8-11717

Variations of Ellipse $\frac{x^2 + 2y^2}{198^2} = 1$ and Circle $\frac{x^2 + y^2}{279.738^2} = 1$ from
 $x = -27.5$ to 27.5



Ellipse

$$D_E = 140.007 - \sqrt{\frac{198^2 - x_n^2}{2}}$$



Circle

$$D_C = 279.238 - \sqrt{279.238^2 - x_n^2}$$

x_n	D_E	D_C
0	0	0
1	.002	.002
2	.007	.007
3	.016	.016
4	.029	.029
5	.043	.043
6	.065	.065
7	.088	.088
8	.115	.114
9	.145	.145
10	.179	.179
11	.217	.217
12	.258	.258
13	.303	.302
14	.351	.350
15	.403	.402
16	.460	.458
17	.518	.517
18	.582	.581
19	.647	.646
20	.717	.716
21	.791	.790
22	.869	.867
23	.949	.948
24	1.033	1.032
25	1.122	1.121
26	1.213	1.213
27	1.309	1.308
27.5	1.359	1.357

REV SYM:

QUALITY CONTROL LABORATORY REPORT Q 28682

Date 8-27-64 Submitted by 3070 - R. Layton Prepared by 3070 - R. Lightstone 3452
DEPT. NO. INSP. OR SHOP SUPV. DEPT. NO. NAME PHONE

Description: R.N. _____ Part No. MR & T-SK-714 P.O. _____ Quantity Rec'd _____

Material 2219-T37 Aluminum Vendor _____

No. of Samples 30 No. of Pieces 30 Spec. No. Fed. T.M. 151 Copies to 3070 - RLayton 1cc
DEPT. NO. NAME

Information Requested Tensile test, ultimate strength, yield, elongation, and reduction in area. 3070 - RLightstone 1cc
USAF - Chief, Q.C. 1cc

HS:mm

The 2219-T37 specimens were tensile tested with results as follow:

SAMPLE NUMBER	DIMENSIONS	AREA SQ. IN.	YIELD LOAD LB.	ULTIMATE LOAD LB.	YIELD STRENGTH PSI	TENSILE STRENGTH PSI	ELONG. %	REDUCTION IN AREA %
130-5812								
L1	0.5044 x 0.2520	0.1271	5,870	7,220	46,200	56,800	19	42.9
L2	0.5048 x 0.2514	0.1269	6,050	7,290	47,700	57,400	19	38.1
L3	0.5038 x 0.2507	0.1263	5,880	7,230	46,600	57,200	19	41.1
T1	0.5053 x 0.2522	0.1274	5,370	7,340	42,100	57,600	17	37.2
T2	0.5041 x 0.2520	0.1270	5,350	7,280	42,100	57,300	16	35.0
T3	0.5029 x 0.2524	0.1269	5,220	7,240	41,100	57,100	18	38.5
13-1903								
L1	0.5040 x 0.5010	0.2525	12,020	14,200	47,600	56,200	21	40.2
L2	0.5020 x 0.4988	0.2504	12,360	14,520	49,100	58,000	22	45.3
L3	0.5028 x 0.5004	0.2516	11,980	13,980	47,600	55,600	22	40.0
L4	0.5032 x 0.5003	0.2518	12,500	14,560	49,600	57,800	23	45.6
T1	0.5028 x 0.5011	0.2520	10,340	14,200	41,000	56,300	22	40.1
T2	0.5031 x 0.5008	0.2520	10,800	14,600	42,900	57,900	21	36.5
13-1904								
L1	0.5050 x 0.4986	0.2518	11,860	14,560	47,100	57,800	21	38.8
L2	0.5032 x 0.4997	0.2514	12,120	14,260	48,200	56,700	23	42.3
L3	0.5024 x 0.5002	0.2513	11,600	14,280	46,200	56,800	22	42.3
L4	0.5030 x 0.5004	0.2517	12,160	14,300	48,300	56,800	21	38.4
T1	0.5038 x 0.5018	0.2528	10,660	14,720	42,200	58,200	22	37.5
T2	0.5034 x 0.4978	0.2506	10,920	14,720	43,600	58,700	20	39.7

- Continued -

Prepared by _____

Approved by _____

SAMPLE NUMBER	DIMENSIONS	AREA SQ. IN.	YIELD LOAD LB.	ULTIMATE LOAD LB.	YIELD STRENGTH PSI	TENSILE STRENGTH PSI	ELONG. %	REDUCTION IN AREA %
<u>181-113</u>								
L1	0.5065	0.2015	9,280	11,250	46,100	55,800	20	43.5
L2	0.5078	0.2025	9,290	11,330	45,900	56,000	21	44.2
L3	0.5079	0.2026	9,280	11,330	45,800	55,900	22	44.2
T1	0.5073	0.2021	8,330	11,520	41,200	57,000	17	32.8
T2	0.5059	0.2010	8,240	11,400	41,000	56,700	18	34.9
T3	0.5042	0.1996	8,130	11,350	40,700	56,900	18	35.8
<u>181-114</u>								
L1	0.5071	0.2020	9,560	11,520	47,300	57,000	20	40.4
L2	0.5039	0.1991	9,430	11,340	47,300	56,900	20	42.0
T1	0.5032	0.1989	8,340	11,540	41,900	58,000	18	34.5
T2	0.5051	0.2004	8,500	11,710	42,400	58,400	16	33.5
T3	0.5046	0.2000	8,370	11,640	41,900	58,200	17	34.5
T4	0.5037	0.1993	8,340	11,540	41,800	57,900	17	35.8

The samples were destroyed in testing and the remnants disposed of as scrap.

Prepared by H. Shapley

Approved by

O.R. Borngesser Original signed by
PAUL C. KISSER

QUALITY CONTROL LABORATORY REPORT Q 34671

Date 12-10-64 Submitted by 3070 - R. Layton Prepared by 3070 - R. Lightstone 3452
DEPT. NO. INSP. OR SHOP SUPV. DEPT. NO. NAME PHONE

Description: R.N. _____ Part No. _____ P.O. _____ Quantity Rec'd _____

Material 2219-T87 Vendor _____

No. of Samples 3 No. of Pieces 3 Spec. No. _____ Copies to 3070 - R. Layton lee
DEPT. NO. NAME

USAF - Chief, Q.C. lee

Information Requested: Please make check in longitudinal and transverse grain direction, for mechanical properties on yield strength, ultimate tensile strength, percent elongation. Samples may be destroyed, return remnants.

BJW:mm

Sample Nos. <u>-3</u>	Part I All F2 Samples - <u>1/4" Plate</u>
<u>131-903-7</u>	Part II All R3 Samples - <u>1/2" Plate</u>
<u>181-114-13</u>	Part III All R1 Samples - <u>3/4" Plate</u>

Test results were as shown by the following data:

PIECE NUMBER	DIMENSIONS	AREA SQ. IN.	YIELD LOAD LB.	ULTIMATE LOAD LB.	YIELD STRENGTH PSI	TENSILE STRENGTH PSI	ELONG. %
L-1-1	0.5053 x 0.2577	0.1302	7,250	8,750	55,700	67,200	12
L-1-2	0.5048 x 0.2590	0.1307	7,250	8,770	55,500	67,100	12
T-1-1	0.5052 x 0.2575	0.1301	7,210	8,770	55,400	67,400	12
T-1-2	0.5014 x 0.2570	0.1289	7,160	8,680	55,500	67,300	11
L-2-1	0.2540	0.0507	2,880	3,490	56,800	68,800	12
L-2-2	0.2540	0.0507	2,840	3,440	56,000	67,800	12
T-2-1	0.2535	0.0505	2,850	3,470	56,400	68,700	11
T-2-2	0.2542	0.0508	2,850	3,470	56,100	68,300	11
L-3-1	0.5100	0.2043	11,660	14,320	57,100	70,100	12
L-3-2	0.5111	0.2051	11,740	14,400	57,200	70,200	12
T-3-1	0.5095	0.2039	11,580	14,320	56,800	70,200	11
T-3-2	0.5080	0.2027	11,520	14,260	56,800	70,400	11

Prepared by B.J. Wade *B.J. Wade* Approved by O.R. Borngesser *Paul Chisner*

FIND DEFLECTION DUE TO

STRESS at CENTER = 49,000 psi (YIELD PT. OF 2219AL)

$$s = \frac{Et^2}{a^2} \left[\frac{1.238}{1-\nu} \left(\frac{y}{t} \right) + .294 \left(\frac{y}{t} \right)^2 \right]^*$$

$$4.9 \cdot 10^4 = \frac{(10.6 \cdot 10^6)(.9)^2}{(27.5)^2} \left[\frac{1.238}{1-.36} \left(\frac{y}{.9} \right) + .294 \left(\frac{y}{.9} \right)^2 \right]$$

$$0 = .413y^2 + 2.44y - 4.9 = 0$$

$$y = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\text{OR } y = +1.60 \text{ in.}$$

FORCE WITH WHICH MAT'L REACTS AGAINST CLAMPING -

$$\frac{wa^4}{Et^4} = \frac{64}{63(1-\nu)} \left(\frac{y}{t} \right) + .376 \left(\frac{y}{t} \right)^3 *$$

$$\frac{w(27.5)^4}{(10.6 \cdot 10^6)(.9)^4} = \frac{64}{63(1-.36)} \left(\frac{1.60}{.9} \right) + .376 \left(\frac{1.60}{.9} \right)^3$$

$$w = 64 \text{ psi}^1$$

TOTAL LOAD = 152,000 lb.

LOAD PER BEAM = 38,000 lb.

MOMENT OF INERTIA NECESSARY TO WITHSTAND LOADINGS:

$$y = \frac{3}{320} \frac{Wl^3}{EI}$$

$$5 \cdot 10^{-3} = \frac{3}{3.2 \cdot 10^2} \frac{(3.8 \cdot 10^4)(68)^3}{(10.6 \cdot 10^6)(I)}$$

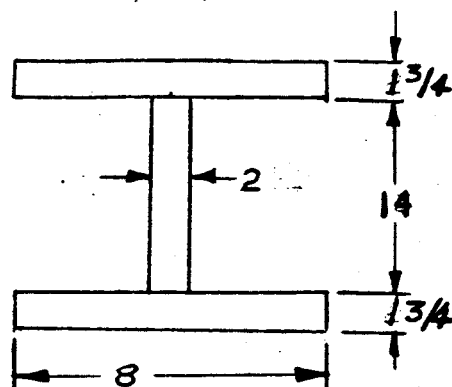
$$I = 2110 \text{ in.}^4$$

1. FORCE WITH WHICH MAT'L. REACTS AGAINST BEING HELD.

* FROM ROARK, R. J., "FORMULAS FOR STRESS & STRAIN"
 CHAP. 10, PAGE 220

CALC	TWKS	11/27/64	REVISED	DATE	MIT-RSC-MR & T-SK-714
CHECK					
APR	K. H. H. H.	7/23/64			
APR					
THE BOEING COMPANY AIRPLANE DIVISION - WICHITA BRANCH WICHITA, KANSAS, 67210					PAGE 1
CONTRACT NO.					STRESS CALCULATIONS

MOMENT OF INERTIA (TYP. SECTION):



$$\begin{aligned}
 I_{\text{TOTAL}} &= \sum \frac{bh^3}{12} + \sum Ad^2 \\
 &= 2 \left[\frac{(8)(1\frac{3}{4})^3}{12} + (8)(2)(7.875)^2 \right] + \frac{(2.00)(14)^3}{12} \\
 &= 2193 \text{ IN}^4
 \end{aligned}$$

WELD LENGTH TO WITHSTAND 19,000 lb. AT CLAMPS:

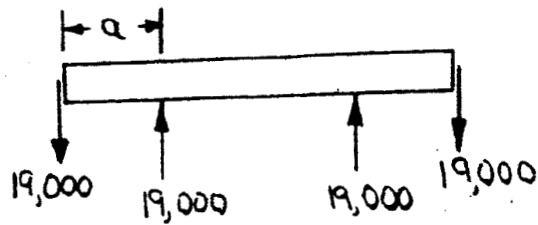
$$\begin{aligned}
 P &= 9.6 \text{ DL} \\
 19 &= 96 (\frac{1}{2})(L) \\
 L &= 3.76 \text{ IN.}
 \end{aligned}$$

P = LOAD IN KIPS
 L = WELD LENGTH
 D = WELD SIZE

R.

CALC	Twiss	7/22/64	REVISED	DATE	MIT-RSC-MR & T-SK-74
CHECK			highston	8/4/64	
APR	Rhighston	7/22/64			
APR					
THE BOEING COMPANY AIRPLANE DIVISION - WICHITA BRANCH WICHITA, KANSAS. 67210					PAGE
CONTRACT NO.					2
STRESS CALCULATIONS					

MOMENT OF INERTIA FOR UPPER PLATE:



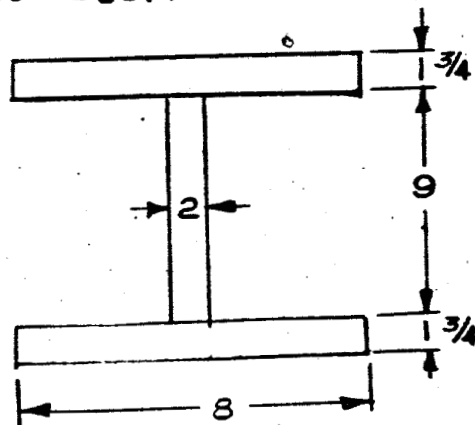
P = TOTAL LOAD
 L = LENGTH OF BEAM

$$y = -\frac{Pa^2}{12EI} (3L - 4a)^*$$

$$-5 \cdot 10^{-3} = -\frac{(38,000)(9)^2}{(12)(10.6 \cdot 10^6)I} (3 \cdot 73 - 4 \cdot 9)$$

$$I = 888 \text{ IN}^4$$

Typ. Cross-Section:



$$I = \frac{bh^3}{12} + Ad^2$$

$$= 2 \left[\frac{(8)(1\frac{3}{4})^3}{12} + (1\frac{3}{4})(8)(5.375)^2 \right] + \frac{(2)(9)^3}{12}$$

$$= 937.12 \text{ IN}^4$$

CALC	Twiss	7/24	REVISED	DATE	MIT-RSC-MR&T-SK-714	3
CHECK						
APR	R. Lightstone	7/23/44				
APR						
CONTRACT NO.					THE BOEING COMPANY AIRPLANE DIVISION - WICHITA BRANCH WICHITA, KANSAS 67210	PAGE
					STRESS CALCULATION:	

MATERIAL: 6061-T6 AL.

ALLOWABLE STRESSES:

TENSILE = 10,000 PSI

COMP = 10,000 PSI

SHEAR = 15,000 PSI

① SHEAR LOAD AT A-A:

$$L = \frac{19000 \text{ LB}}{2} = 9500 \text{ LB.}$$

ALLOWABLE LOAD AT A-A

$$L = 1.5 \times 1.75 \times 15000 \text{ LB} = 39,375 \text{ LBS}$$

② TENSILE LOAD AT B-B: (MIN AREA)

$$L = \frac{19000 \text{ LB}}{2} = 9500 \text{ LBS}$$

$$\text{ALLOWABLE LOAD} = .875 \times 1.5 \times 10,000 \text{ PSI} = 13,125 \text{ LB. } \underline{\text{Rev.}}$$

③ TENSILE LOAD AT C-C:

$$L = 19000 \text{ LBS}$$

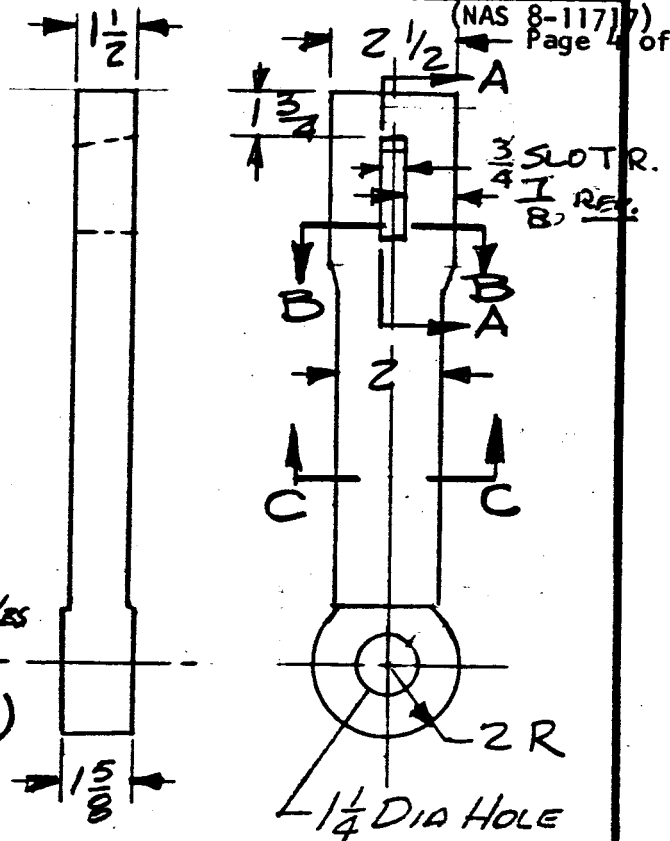
$$\text{ALLOWABLE LOAD AT C-C} = 2 \times 1.5 \times 10,000 \text{ PSI} = 30,000 \text{ LBS}$$

④ COMPRESSIVE STRESS AT PIN:

t = THICKNESS d = DIAMETER

$$\text{COMPRESSIVE AREA} = t d = 1.63 \times 1.25 = 2.0375$$

$$\text{COMPRESSIVE STRESS} = \frac{19000}{2.0375} = 9,327 \text{ LB}$$



CALC	C. NELSON	3/4/64	REVISED	DATE	MIT-RSC-MR&T-SK-714
CHECK				8/7/64	
APR	R. H. Galt	8/2/64		8/11/64	
APR					
THE BOEING COMPANY AIRPLANE DIVISION - WICHITA BRANCH WICHITA, KANSAS. 67210					PAGE
CONTRACT NO.					4
STRESS CALCULATIONS					

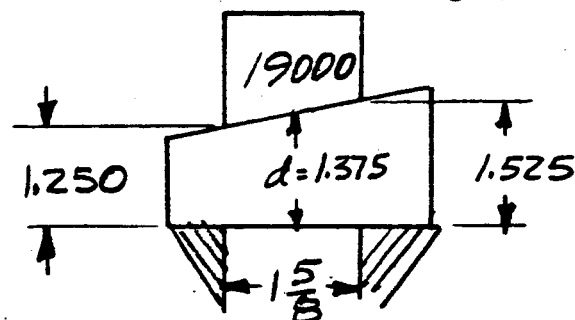
CALCULATIONS FOR LOCK WEDGE

MAT'L = 6061-T6 AL.

LOAD P = 19000 LBS

SPAN L = 1.63

R. SAFETY FACTOR = 2



$$M_0 = \frac{PL}{8} = \frac{19000 \times 1.625}{8} = \frac{31,825}{8} = 3978 \text{ IN/LBS}$$

WEDGE THICKNESS $t = .500$

$$S_c = \frac{M c}{I} = M \frac{t}{b d^2}$$

$$R \ 20000 = 3978 \text{ IN/LB} \cdot \frac{t}{.5 \times d^2}$$

$$R \ d = \sqrt{\frac{3978 \times t}{20000 \times .75}} = \sqrt{1.591}$$

$$R \ d = 1.265$$

$$d \text{ (ACTUAL)} = 1.375$$

MAXIMUM SHEAR LOAD = 19000 LB

ALLOWABLE SHEAR LOAD =

$$(.5 \times 1.250 + .5 \times 1.525) (15000) = 20,813 \text{ LBS}$$

CALC	C. NELSON	8/4/4	REVISED	DATE	MIT-RSC-MR&T-SK-714
CHECK			WIGGISTON	8/7/4	
APR	WIGGISTON	8/4/64			
APR					
THE BOEING COMPANY AIRPLANE DIVISION - WICHITA BRANCH WICHITA, KANSAS. 67210					PAGE
CONTRACT NO.					5

Proj. 28-43
(NAS 8-1717)
Page 1 of 1

Part No.	Thick- ness T	Contour	Grain Direc- tion	Chord Height CH	Chord Length CL	Rp = $\frac{4CH^2+CL^2}{8(CH)}$	Sp = $\frac{T}{2R}$	RF (Fix- ture)	SF (Fix- ture)	Reten- tion % SF 100	Reten- tion % CH ² 100	Arc Length at 50" CL	Lineal Growth In./In.	Thick. Growth In./In.	THIS PANEL DATA IS IN OBVIOUS ERROR. REASON HAS NOT BEEN DETERMINED - (1ST PART FORMER)
1	.250"	Std.	Long.	1.109	54	329.22	.000380	279.238	.000448	84.8	84.79	50.055	.0011		
2	.250"	Std.	Trans	.896	54	407.255	.000307	279.238	.000448	68.57	68.50	50.080	.0016		
3	.250"	Std.	Long.	1.016	54	359.268	.000348	279.238	.000448	77.68	77.68	50.090			
4	.250"	Std.	Trans	1.020	54	357.863	.000349	279.238	.000448	77.90	77.98	50.095			
5	.250"	Std.	Long.	1.101	54	331.610	.000377	279.238	.000448	84.15	84.17	50.065	.0013		
6	.250"	Std.	Trans	.917	54	397.950	.000314	279.238	.000448	70.09	70.11	50.085	.0017		
7	.250"	Std.	Long.	1.653	54	221.335	.00057	189.340	.00066	86.36	85.42	50.100	.0020		
8	.250"	Std.	Trans	1.521	54	240.405	.00052	189.340	.00066	78.79	78.60	50.115	.0023		
9	.250"	Std.	Long.	1.752	54	208.924	.000598	189.340	.00066	90.60	90.54	50.113	.00236		
10	.250"	Std.	Trans	1.459	54	250.558	.000499	189.340	.00066	75.61	75.40	50.115	.0023		
11	.250"	Std.	Long.	1.752	54	219.620	.000569	189.340	.00066	86.21	86.10	50.120	.0024	.0024	
12	.250"	Std.	Trans	1.506	54	242.785	.000515	189.340	.00066	78.03	77.83	50.120	.0024	.0036	
13	.500"	Std.	Long.	1.065	54	345.699	.000723	279.238	.000895	80.78	80.42	50.110	.0022		
14	.500"	Std.	Trans	.916	54	397.086	.000630	279.238	.000895	70.39	70.26	50.120	.0024		
15	.500"	Std.	Long.	1.020	54	357.863	.000699	279.238	.000895	78.10	77.98	50.110	.0022		
16	.500"	Std.	Trans	.936	54	389.890	.000641	279.238	.000895	71.62	71.95	50.120	.0024		
17	.500"	Std.	Long.	1.086	54	336.178	.000744	279.238	.000895	83.13	83.03	50.110	.0022		
18	.500"	Std.	Trans	.922	54	395.369	.000632	279.238	.000895	70.61	70.48	50.115	.0023		
19	.500"	Std.	Long.	1.652	54	221.464	.001123	189.340	.001320	85.53	85.37	50.140	.0028		
20	.500"	Std.	Trans	1.426	54	256.323	.000975	189.340	.001320	73.86	73.69	50.145	.0029		
21	.500"	Std.	Long.	1.669	54	219.229	.001140	189.340	.001320	86.36	86.25	50.145	.0029	.0020	
22	.500"	Std.	Trans	1.447	54	252.623	.000990	189.340	.001320	75.00	74.78	50.145	.0029	.0026	
23	.500"	Std.	Long.	1.660	54	220.408	.001134	189.340	.001320	85.91	86.25	50.145	.0029		
24	.500"	Std.	Trans	1.448	54	252.451	.00099	189.340	.001320	75.00	74.78	50.145	.0029		
25	.900"	Std.	Long.	1.035	54	352.691	.001276	279.238	.001612	79.16	79.13	50.135	.0027	.0017	
26	.900"	Std.	Trans	.926	54	394.518	.00114	279.238	.001612	70.72	70.80	50.142	.0028	.0019	
27	.900"	Std.	Long.	.980	54	372.429	.001208	279.238	.001612	74.94	74.92	50.130	.0026	.0019	
28	.900"	Std.	Trans	.886	54	411.843	.001093	279.238	.001612	67.80	67.74	50.135	.0027	.0020	
29	.900"	Std.	Long.	.980	54	372.429	.001208	279.238	.001612	74.94	74.92	50.135	.0027		
30	.900"	Std.	Trans	.880	54	414.645	.001085	279.238	.001612	67.31	67.28	50.130	.0026		
31	.900"	Std.	Long.	1.624	54	225.258	.001998	189.340	.002377	84.06	84.93	50.180	.0036		
32	.900"	Std.	Trans	1.469	54	248.863	.001800	189.340	.002377	76.06	75.92	50.185	.0037		
33	.900"	Std.	Long.	1.560	54	234.434	.001920	189.340	.002377	80.77	80.98	50.165	.0033		
34	.900"	Std.	Trans	1.416	54	258.123	.001743	189.340	.002377	73.33	73.18	50.175	.0035		
35	.900"	Std.	Long.	1.612	54	226.923	.001983	189.340	.002377	83.42	83.30	50.172	.0035		
36	.900"	Std.	Trans	1.478	54	247.356	.001819	189.340	.002377	76.53	76.38	50.170	.0034		
						SUMMATION OF WORK SHEETS	----			NAS 8-1717					

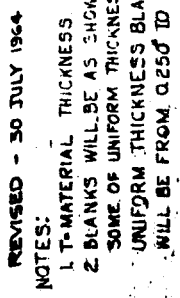
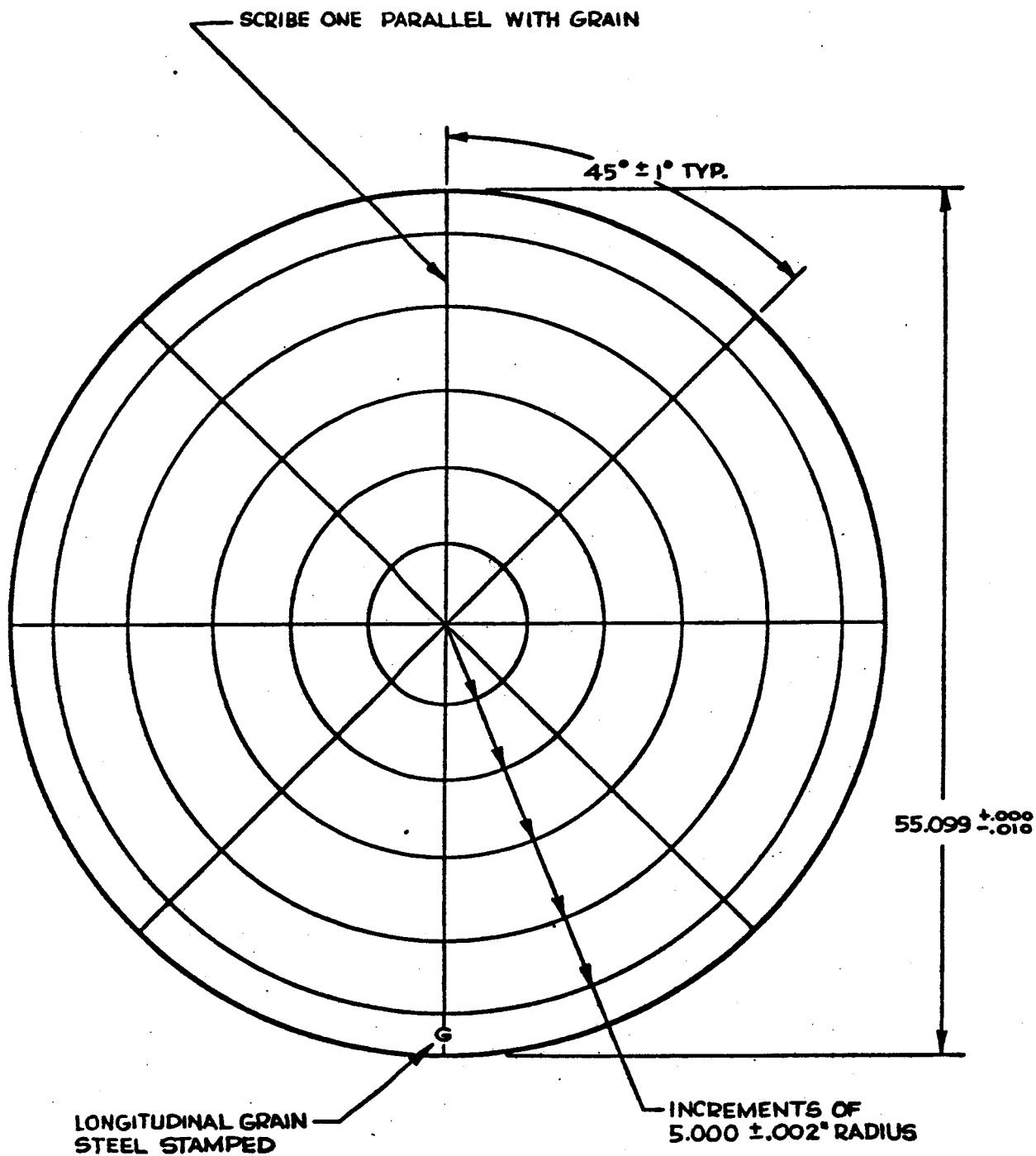


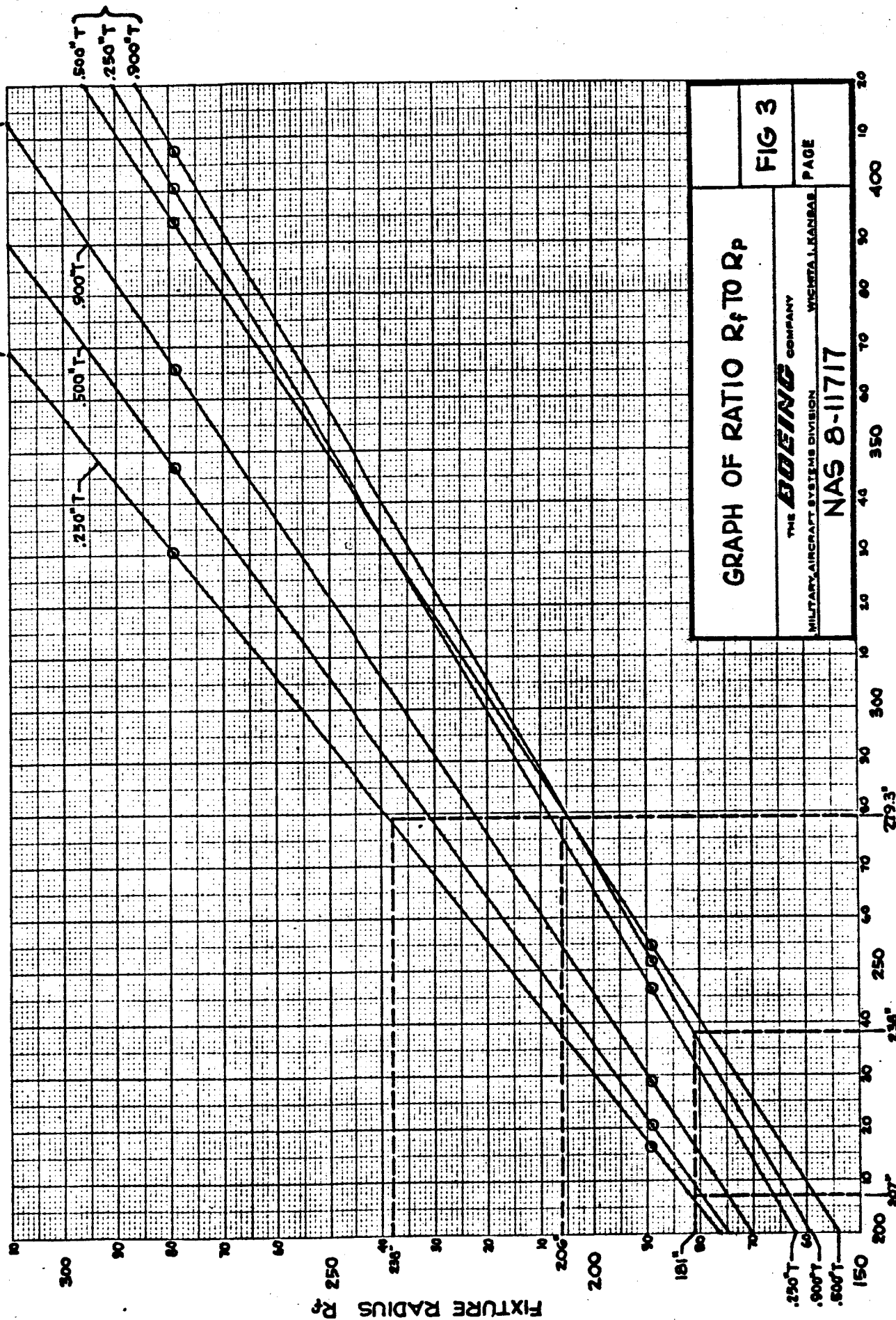
FIG. 1
NAS 8-11717

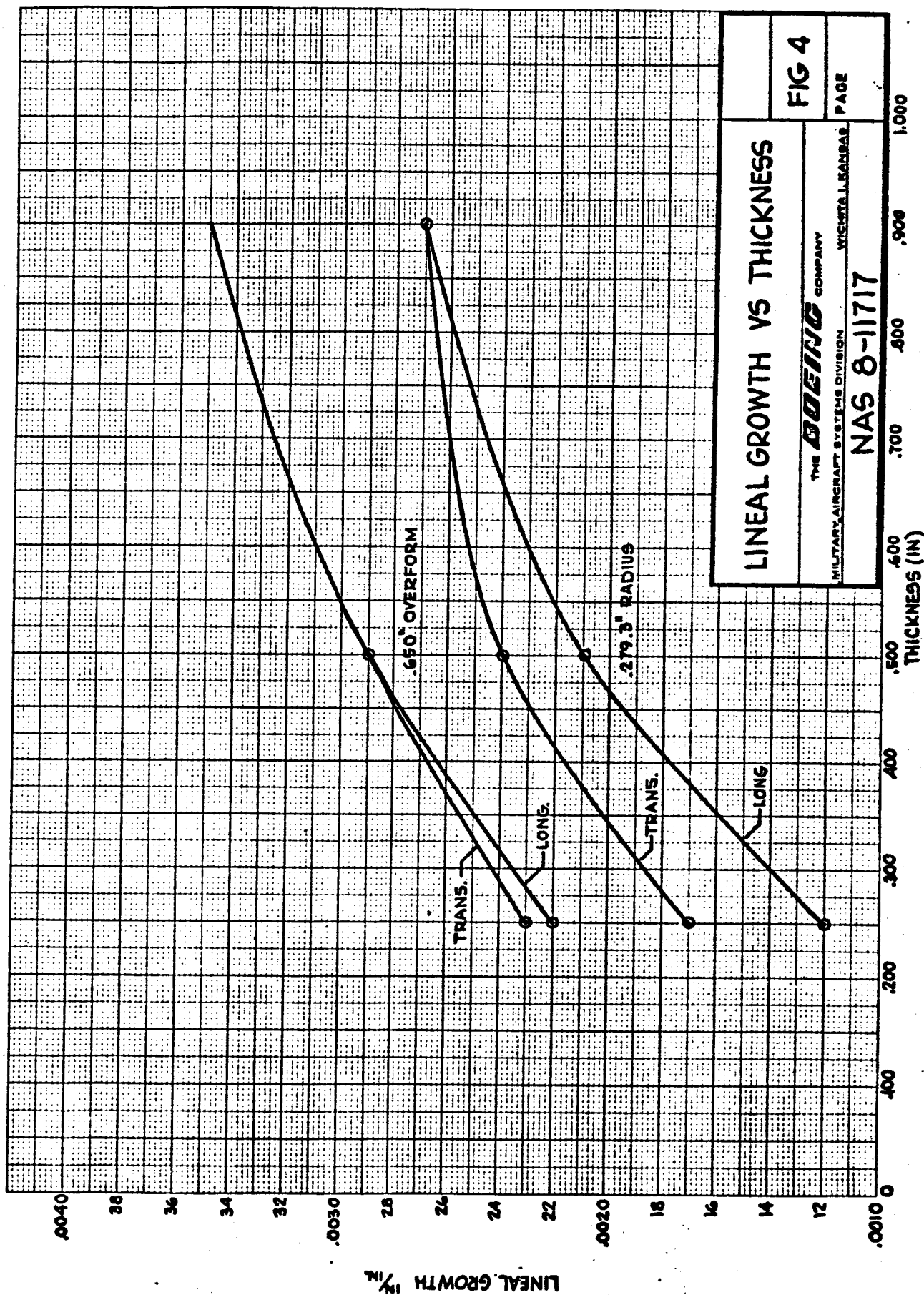
1. TITLE MECHANICAL DESIGN		2. PROJECT NO. 1-330		3. DATE 1/17/68		4. CENTER LOWER HEAD FUEL TANK	
5. DRAWING NO. 1-330		6. REV. 1-330		7. DESIGNED BY 1-330		8. CHECKED BY 1-330	
9. PROJECT NAME 219 A. Alloy		10. PROJECT NO. 1-330		11. PROJECT NO. 1-330		12. PROJECT NO. 1-330	
13. PROJECT NO. 1-330		14. PROJECT NO. 1-330		15. PROJECT NO. 1-330		16. PROJECT NO. 1-330	
17. PROJECT NO. 1-330		18. PROJECT NO. 1-330		19. PROJECT NO. 1-330		20. PROJECT NO. 1-330	
21. PROJECT NO. 1-330		22. PROJECT NO. 1-330		23. PROJECT NO. 1-330		24. PROJECT NO. 1-330	
25. PROJECT NO. 1-330		26. PROJECT NO. 1-330		27. PROJECT NO. 1-330		28. PROJECT NO. 1-330	
29. PROJECT NO. 1-330		30. PROJECT NO. 1-330		31. PROJECT NO. 1-330		32. PROJECT NO. 1-330	
33. PROJECT NO. 1-330		34. PROJECT NO. 1-330		35. PROJECT NO. 1-330		36. PROJECT NO. 1-330	
37. PROJECT NO. 1-330		38. PROJECT NO. 1-330		39. PROJECT NO. 1-330		40. PROJECT NO. 1-330	
41. PROJECT NO. 1-330		42. PROJECT NO. 1-330		43. PROJECT NO. 1-330		44. PROJECT NO. 1-330	
45. PROJECT NO. 1-330		46. PROJECT NO. 1-330		47. PROJECT NO. 1-330		48. PROJECT NO. 1-330	
49. PROJECT NO. 1-330		50. PROJECT NO. 1-330		51. PROJECT NO. 1-330		52. PROJECT NO. 1-330	
53. PROJECT NO. 1-330		54. PROJECT NO. 1-330		55. PROJECT NO. 1-330		56. PROJECT NO. 1-330	
57. PROJECT NO. 1-330		58. PROJECT NO. 1-330		59. PROJECT NO. 1-330		60. PROJECT NO. 1-330	
61. PROJECT NO. 1-330		62. PROJECT NO. 1-330		63. PROJECT NO. 1-330		64. PROJECT NO. 1-330	
65. PROJECT NO. 1-330		66. PROJECT NO. 1-330		67. PROJECT NO. 1-330		68. PROJECT NO. 1-330	
69. PROJECT NO. 1-330		70. PROJECT NO. 1-330		71. PROJECT NO. 1-330		72. PROJECT NO. 1-330	
73. PROJECT NO. 1-330		74. PROJECT NO. 1-330		75. PROJECT NO. 1-330		76. PROJECT NO. 1-330	
77. PROJECT NO. 1-330		78. PROJECT NO. 1-330		79. PROJECT NO. 1-330		80. PROJECT NO. 1-330	
81. PROJECT NO. 1-330		82. PROJECT NO. 1-330		83. PROJECT NO. 1-330		84. PROJECT NO. 1-330	
85. PROJECT NO. 1-330		86. PROJECT NO. 1-330		87. PROJECT NO. 1-330		88. PROJECT NO. 1-330	
89. PROJECT NO. 1-330		90. PROJECT NO. 1-330		91. PROJECT NO. 1-330		92. PROJECT NO. 1-330	
93. PROJECT NO. 1-330		94. PROJECT NO. 1-330		95. PROJECT NO. 1-330		96. PROJECT NO. 1-330	
97. PROJECT NO. 1-330		98. PROJECT NO. 1-330		99. PROJECT NO. 1-330		100. PROJECT NO. 1-330	
101. PROJECT NO. 1-330		102. PROJECT NO. 1-330		103. PROJECT NO. 1-330		104. PROJECT NO. 1-330	
105. PROJECT NO. 1-330		106. PROJECT NO. 1-330		107. PROJECT NO. 1-330		108. PROJECT NO. 1-330	
109. PROJECT NO. 1-330		110. PROJECT NO. 1-330		111. PROJECT NO. 1-330		112. PROJECT NO. 1-330	
113. PROJECT NO. 1-330		114. PROJECT NO. 1-330		115. PROJECT NO. 1-330		116. PROJECT NO. 1-330	
117. PROJECT NO. 1-330		118. PROJECT NO. 1-330		119. PROJECT NO. 1-330		120. PROJECT NO. 1-330	
121. PROJECT NO. 1-330		122. PROJECT NO. 1-330		123. PROJECT NO. 1-330		124. PROJECT NO. 1-330	
125. PROJECT NO. 1-330		126. PROJECT NO. 1-330		127. PROJECT NO. 1-330		128. PROJECT NO. 1-330	
129. PROJECT NO. 1-330		130. PROJECT NO. 1-330		131. PROJECT NO. 1-330		132. PROJECT NO. 1-330	
133. PROJECT NO. 1-330		134. PROJECT NO. 1-330		135. PROJECT NO. 1-330		136. PROJECT NO. 1-330	
137. PROJECT NO. 1-330		138. PROJECT NO. 1-330		139. PROJECT NO. 1-330		140. PROJECT NO. 1-330	
141. PROJECT NO. 1-330		142. PROJECT NO. 1-330		143. PROJECT NO. 1-330		144. PROJECT NO. 1-330	
145. PROJECT NO. 1-330		146. PROJECT NO. 1-330		147. PROJECT NO. 1-330		148. PROJECT NO. 1-330	
149. PROJECT NO. 1-330		150. PROJECT NO. 1-330		151. PROJECT NO. 1-330		152. PROJECT NO. 1-330	
153. PROJECT NO. 1-330		154. PROJECT NO. 1-330		155. PROJECT NO. 1-330		156. PROJECT NO. 1-330	
157. PROJECT NO. 1-330		158. PROJECT NO. 1-330		159. PROJECT NO. 1-330		160. PROJECT NO. 1-330	
161. PROJECT NO. 1-330		162. PROJECT NO. 1-330		163. PROJECT NO. 1-330		164. PROJECT NO. 1-330	
165. PROJECT NO. 1-330		166. PROJECT NO. 1-330		167. PROJECT NO. 1-330		168. PROJECT NO. 1-330	
169. PROJECT NO. 1-330		170. PROJECT NO. 1-330		171. PROJECT NO. 1-330		172. PROJECT NO. 1-330	
173. PROJECT NO. 1-330		174. PROJECT NO. 1-330		175. PROJECT NO. 1-330		176. PROJECT NO. 1-330	
177. PROJECT NO. 1-330		178. PROJECT NO. 1-330		179. PROJECT NO. 1-330		180. PROJECT NO. 1-330	
181. PROJECT NO. 1-330		182. PROJECT NO. 1-330		183. PROJECT NO. 1-330		184. PROJECT NO. 1-330	
185. PROJECT NO. 1-330		186. PROJECT NO. 1-330		187. PROJECT NO. 1-330		188. PROJECT NO. 1-330	
189. PROJECT NO. 1-330		190. PROJECT NO. 1-330		191. PROJECT NO. 1-330		192. PROJECT NO. 1-330	
193. PROJECT NO. 1-330		194. PROJECT NO. 1-330		195. PROJECT NO. 1-330		196. PROJECT NO. 1-330	
197. PROJECT NO. 1-330		198. PROJECT NO. 1-330		199. PROJECT NO. 1-330		200. PROJECT NO. 1-330	
201. PROJECT NO. 1-330		202. PROJECT NO. 1-330		203. PROJECT NO. 1-330		204. PROJECT NO. 1-330	
205. PROJECT NO. 1-330		206. PROJECT NO. 1-330		207. PROJECT NO. 1-330		208. PROJECT NO. 1-330	
209. PROJECT NO. 1-330		210. PROJECT NO. 1-330		211. PROJECT NO. 1-330		212. PROJECT NO. 1-330	
213. PROJECT NO. 1-330		214. PROJECT NO. 1-330		215. PROJECT NO. 1-330		216. PROJECT NO. 1-330	
217. PROJECT NO. 1-330		218. PROJECT NO. 1-330		219. PROJECT NO. 1-330		220. PROJECT NO. 1-330	
221. PROJECT NO. 1-330		222. PROJECT NO. 1-330		223. PROJECT NO. 1-330		224. PROJECT NO. 1-330	
225. PROJECT NO. 1-330		226. PROJECT NO. 1-330		227. PROJECT NO. 1-330		228. PROJECT NO. 1-330	
229. PROJECT NO. 1-330		230. PROJECT NO. 1-330		231. PROJECT NO. 1-330		232. PROJECT NO. 1-330	
233. PROJECT NO. 1-330		234. PROJECT NO. 1-330		235. PROJECT NO. 1-330		236. PROJECT NO. 1-330	
237. PROJECT NO. 1-330		238. PROJECT NO. 1-330		239. PROJECT NO. 1-330		240. PROJECT NO. 1-330	
241. PROJECT NO. 1-330		242. PROJECT NO. 1-330		243. PROJECT NO. 1-330		244. PROJECT NO. 1-330	
245. PROJECT NO. 1-330		246. PROJECT NO. 1-330		247. PROJECT NO. 1-330		248. PROJECT NO. 1-330	
249. PROJECT NO. 1-330		250. PROJECT NO. 1-330		251. PROJECT NO. 1-330		252. PROJECT NO. 1-330	
253. PROJECT NO. 1-330		254. PROJECT NO. 1-330		255. PROJECT NO. 1-330		256. PROJECT NO. 1-330	
257. PROJECT NO. 1-330		258. PROJECT NO. 1-330		259. PROJECT NO. 1-330		260. PROJECT NO. 1-330	
261. PROJECT NO. 1-330		262. PROJECT NO. 1-330		263. PROJECT NO. 1-330		264. PROJECT NO. 1-330	
265. PROJECT NO. 1-330		266. PROJECT NO. 1-330		267. PROJECT NO. 1-330		268. PROJECT NO. 1-330	
269. PROJECT NO. 1-330		270. PROJECT NO. 1-330		271. PROJECT NO. 1-330		272. PROJECT NO. 1-330	
273. PROJECT NO. 1-330		274. PROJECT NO. 1-330		275. PROJECT NO. 1-330		276. PROJECT NO. 1-330	
277. PROJECT NO. 1-330		278. PROJECT NO. 1-330		279. PROJECT NO. 1-330		280. PROJECT NO. 1-330	
281. PROJECT NO. 1-330		282. PROJECT NO. 1-330		283. PROJECT NO. 1-330		284. PROJECT NO. 1-330	
285. PROJECT NO. 1-330		286. PROJECT NO. 1-330		287. PROJECT NO. 1-330		288. PROJECT NO. 1-330	
289. PROJECT NO. 1-330		290. PROJECT NO. 1-330		291. PROJECT NO. 1-330		292. PROJECT NO. 1-330	
293. PROJECT NO. 1-330		294. PROJECT NO. 1-330		295. PROJECT NO. 1-330		296. PROJECT NO. 1-330	
297. PROJECT NO. 1-330		298. PROJECT NO. 1-330		299. PROJECT NO. 1-330		300. PROJECT NO. 1-330	
301. PROJECT NO. 1-330		302. PROJECT NO. 1-330		303. PROJECT NO. 1-330		304. PROJECT NO. 1-330	
305. PROJECT NO. 1-330		306. PROJECT NO. 1-330		307. PROJECT NO. 1-330		308. PROJECT NO. 1-330	
309. PROJECT NO. 1-330		310. PROJECT NO. 1-330		311. PROJECT NO. 1-330		312. PROJECT NO. 1-330	
313. PROJECT NO. 1-330		314. PROJECT NO. 1-330		315. PROJECT NO. 1-330		316. PROJECT NO. 1-330	
317. PROJECT NO. 1-330		318. PROJECT NO. 1-330		319. PROJECT NO. 1-330		320. PROJECT NO. 1-330	
321. PROJECT NO. 1-330		322. PROJECT NO. 1-330		323. PROJECT NO. 1-330		324. PROJECT NO. 1-330	
325. PROJECT NO. 1-330		326. PROJECT NO. 1-330		327. PROJECT NO. 1-330		328. PROJECT NO. 1-330	
329. PROJECT NO. 1-330		330. PROJECT NO. 1-330		331. PROJECT NO. 1-330		332. PROJECT NO. 1-330	
333. PROJECT NO. 1-330		334. PROJECT NO. 1-330		335. PROJECT NO. 1-330		336. PROJECT NO. 1-330	
337. PROJECT NO. 1-330		338. PROJECT NO. 1-330		339. PROJECT NO. 1-330		340. PROJECT NO. 1-330	
341. PROJECT NO. 1-330		342. PROJECT NO. 1-330		343. PROJECT NO. 1-330		344. PROJECT NO. 1-330	
345. PROJECT NO. 1-330		346. PROJECT NO. 1-330		347. PROJECT NO. 1-330		348. PROJECT NO. 1-330	
349. PROJECT NO. 1-330		350. PROJECT NO. 1-330		351. PROJECT NO. 1-330		352. PROJECT NO. 1-330	
353. PROJECT NO. 1-330		354. PROJECT NO. 1-330		355. PROJECT NO. 1-330		356. PROJECT NO. 1-330	
357. PROJECT NO. 1-330		358. PROJECT NO. 1-330		359. PROJECT NO. 1-330		360. PROJECT NO. 1-330	
361. PROJECT NO. 1-330		362. PROJECT NO. 1-330		363. PROJECT NO. 1-330		364. PROJECT NO. 1-330	
365. PROJECT NO. 1-330		366. PROJECT NO. 1-330		367. PROJECT NO. 1-330		368. PROJECT NO. 1-330	
369. PROJECT NO. 1-330		370. PROJECT NO. 1-330		371. PROJECT NO. 1-330		372. PROJECT NO. 1-330	
373. PROJECT NO. 1-330		374. PROJECT NO. 1-330		375. PROJECT NO. 1-330		376. PROJECT NO. 1-330	
377. PROJECT NO. 1-330		378. PROJECT NO. 1-330		379. PROJECT NO. 1-330		380. PROJECT NO. 1-330	
381. PROJECT NO. 1-330		382. PROJECT NO. 1-330		383. PROJECT NO. 1-330		384. PROJECT NO. 1-330	
385. PROJECT NO. 1-330		386. PROJECT NO. 1-330		387. PROJECT NO. 1-330		388. PROJECT NO. 1-330	
389. PROJECT NO. 1-330		390. PROJECT NO. 1-330		391. PROJECT NO. 1-330		392. PROJECT NO. 1-330	
393. PROJECT NO. 1-330		394. PROJECT NO. 1-330		395. PROJECT NO. 1-330		396. PROJECT NO. 1-330	
397. PROJECT NO. 1-330		398. PROJECT NO. 1-330		399. PROJECT NO. 1-330		400. PROJECT NO. 1-330	
401. PROJECT NO. 1-330		402. PROJECT NO. 1-330		403. PROJECT NO. 1-330		404. PROJECT NO. 1-330	
405. PROJECT NO. 1-330		406. PROJECT NO. 1-330		407. PROJECT NO. 1-330		408. PROJECT NO. 1-330	
409. PROJECT NO. 1-330		410. PROJECT NO. 1-330		411. PROJECT NO. 1-330		412. PROJECT NO. 1-330	
413. PROJECT NO. 1-330		414. PROJECT NO. 1-330		415. PROJECT NO. 1-330		416. PROJECT NO. 1-330	
417. PROJECT NO. 1-330		418. PROJECT NO. 1-330		419. PROJECT NO. 1-330		420. PROJECT NO. 1-330	
421. PROJECT NO. 1-330		422. PROJECT NO. 1-330		423. PROJECT NO. 1-330		424. PROJECT NO. 1-330	
425. PROJECT NO. 1-330		426. PROJECT NO. 1-330		427. PROJECT NO. 1-330		428. PROJECT NO. 1-330	
429. PROJECT NO. 1-330		430. PROJECT NO. 1-330		431. PROJECT NO. 1-330		432. PROJECT NO. 1-330	
433. PROJECT NO. 1-330		434. PROJECT NO. 1-330		435. PROJECT NO. 1-330		436. PROJECT NO. 1-330	
437. PROJECT NO. 1-330		438. PROJECT NO. 1-330		439. PROJECT NO. 1-330		440. PROJECT NO. 1-330	
441. PROJECT NO. 1-330		442. PROJECT NO. 1-330		443. PROJECT NO. 1-330		444. PROJECT NO. 1-330	
445. PROJECT NO. 1-330		446. PROJECT NO. 1-330		447. PROJECT NO. 1-330		448. PROJECT NO. 1-330	
449. PROJECT NO. 1-330		450. PROJECT NO. 1-330		451. PROJECT NO. 1-330		452. PROJECT NO. 1-330	
453. PROJECT NO. 1-330		454. PROJECT NO. 1-330		455. PROJECT NO. 1-330		456. PROJECT NO. 1-330	
457. PROJECT NO. 1-330		458. PROJECT NO. 1-330		459. PROJECT NO. 1-330		460. PROJECT NO. 1-330	
461. PROJECT NO. 1-330		462. PROJECT NO. 1-330		463. PROJECT NO. 1-33			



CALC			REVISED	DATE	GRID PATTERN	FIG. 2
CHECK						
APR						
APR						
CONTRACT NO. NAS 8-11717					PAGE	

LONG.

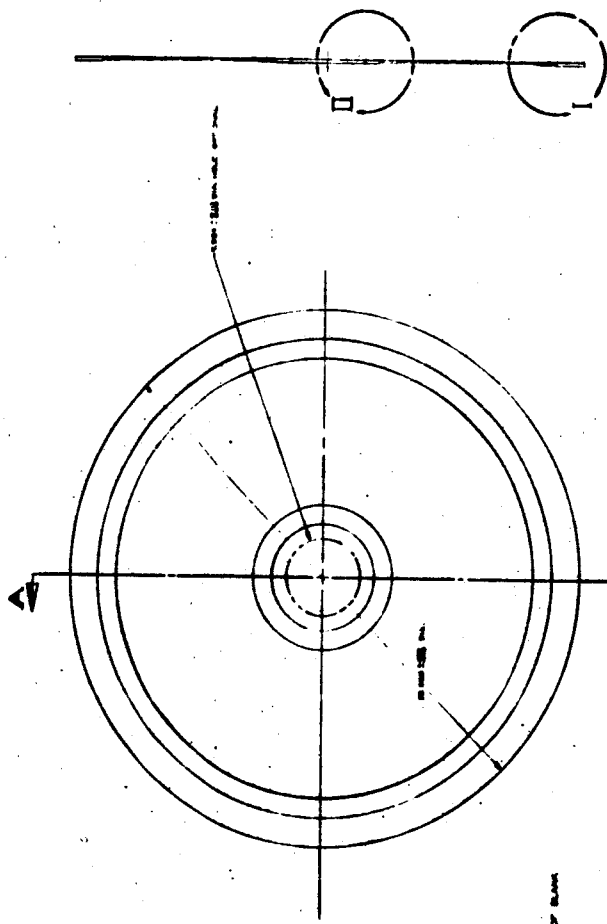




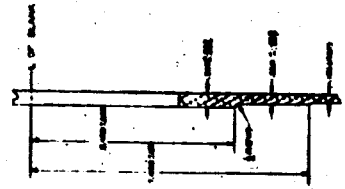
LINEAL GROWTH VS THICKNESS		FIG 4
THE BOEING COMPANY		PAGE
MILITARY AIRCRAFT SYSTEMS DIVISION		
N/A 8-11717		

LINEAL GROWTH

FIG.4



① SECTION FROM
PLAN VIEW



VIEW II

VIEW I

MAINTAIN GRAIN DIRECTION

REMARKS: SHOWING COMPENSATE FOR GROWTH
OF MATERIAL FORMING THE SHAFT
OF THE SHAFT. THE FOLLOWING
RATES OF GROWTH AS FOLLOWS
8013 FROM 1900 TO 1903
8013 FROM 1903 TO 1904

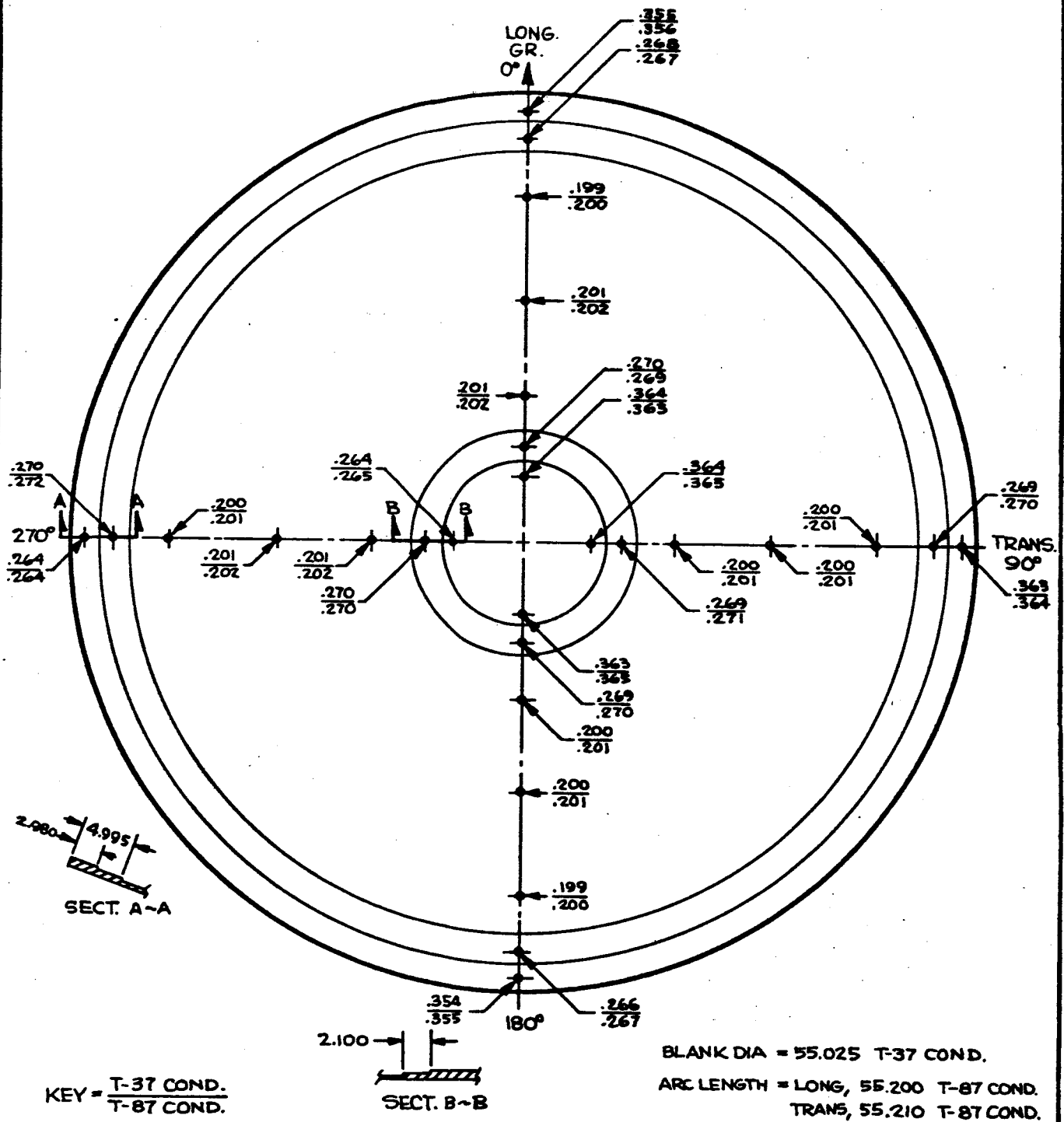
DO NOT SCALE THIS DRAWING

DATE	BY	CHKD	APP'D	REVISION
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	1
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	2
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	3
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	4
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	5
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	6
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	7
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	8
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	9
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	10
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	11
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	12
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	13
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	14
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	15
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	16
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	17
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	18
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	19
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	20
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	21
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	22
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	23
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	24
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	25
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	26
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	27
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	28
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	29
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	30
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	31
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	32
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	33
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	34
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	35
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	36
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	37
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	38
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	39
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	40
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	41
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	42
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	43
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	44
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	45
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	46
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	47
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	48
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	49
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	50
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	51
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	52
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	53
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	54
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	55
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	56
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	57
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	58
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	59
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	60
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	61
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	62
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	63
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	64
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	65
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	66
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	67
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	68
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	69
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	70
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	71
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	72
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	73
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	74
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	75
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	76
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	77
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	78
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	79
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	80
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	81
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	82
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	83
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	84
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	85
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	86
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	87
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	88
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	89
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	90
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	91
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	92
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	93
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	94
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	95
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	96
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	97
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	98
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	99
10/1/54	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS	100

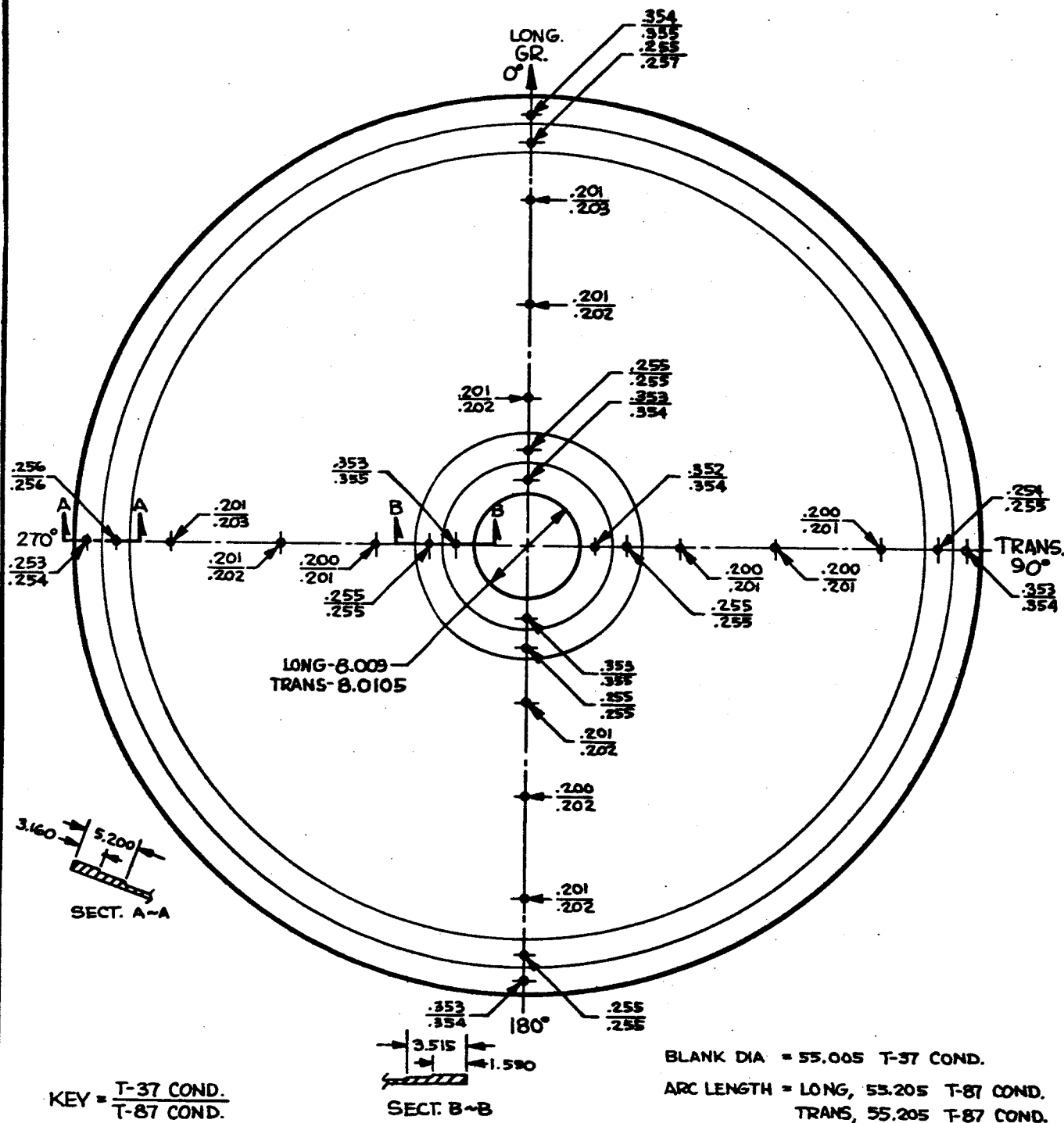
②

③

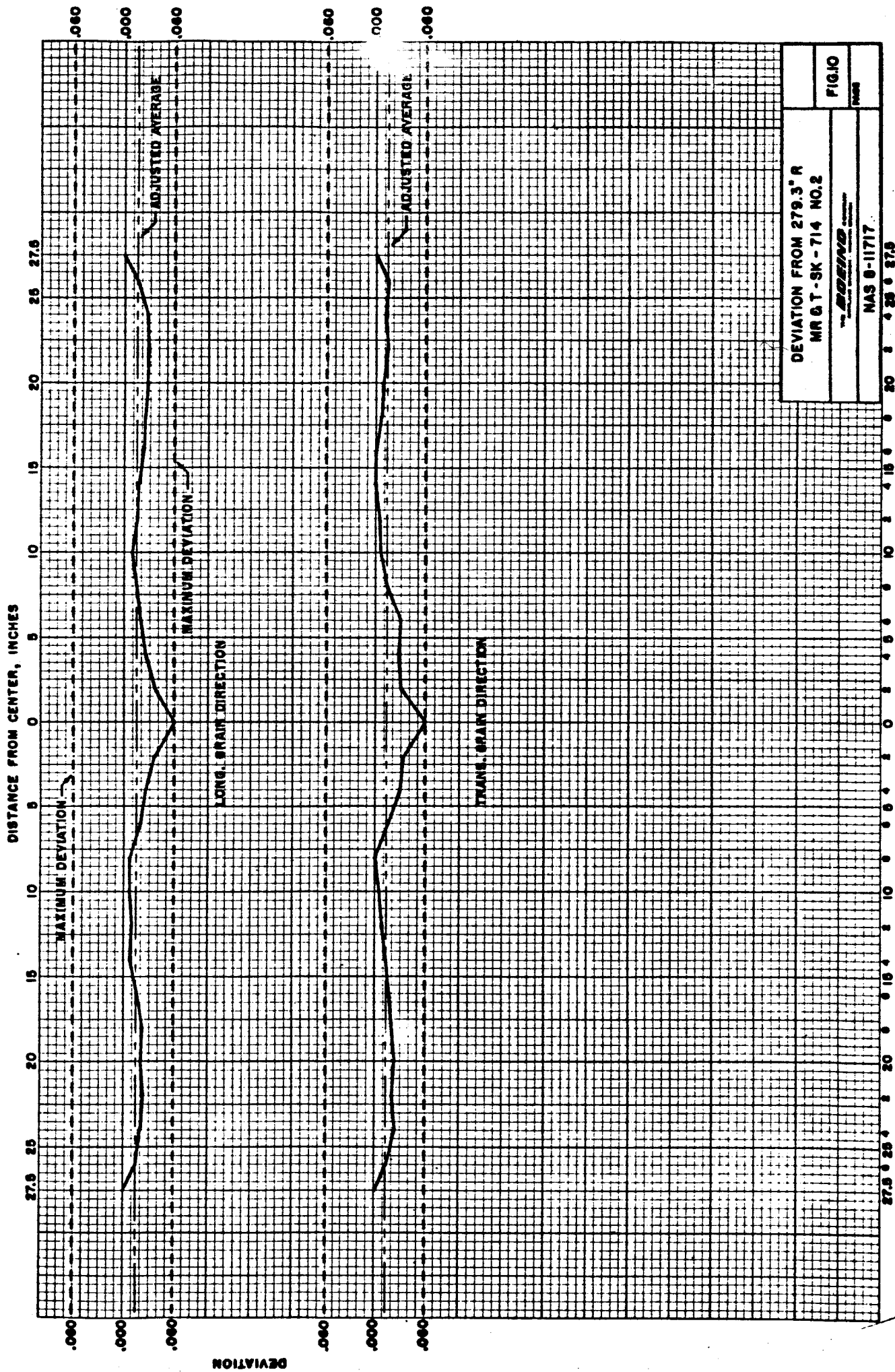
④



CALC			REVISED	DATE	MR-T-SK-714 PART NO. 2 MATERIAL GROWTH	FIG. 7
CHECK						
APR					THE BOEING COMPANY AIRPLANE DIVISION - WICKIUM BRANCH	PAGE
APR						
CONTRACT NO. NAS 8-11717						



CALC			REVISED	DATE	MR 1/2 T-SK-714 PART NO.3 MATERIAL GROWTH	FIG. 8
CHECK						
APR						
APR						
CONTRACT NO. NAS 8-11717					THE BOEING COMPANY AIRPLANE DIVISION • WICHITA, KANSAS	PAGE

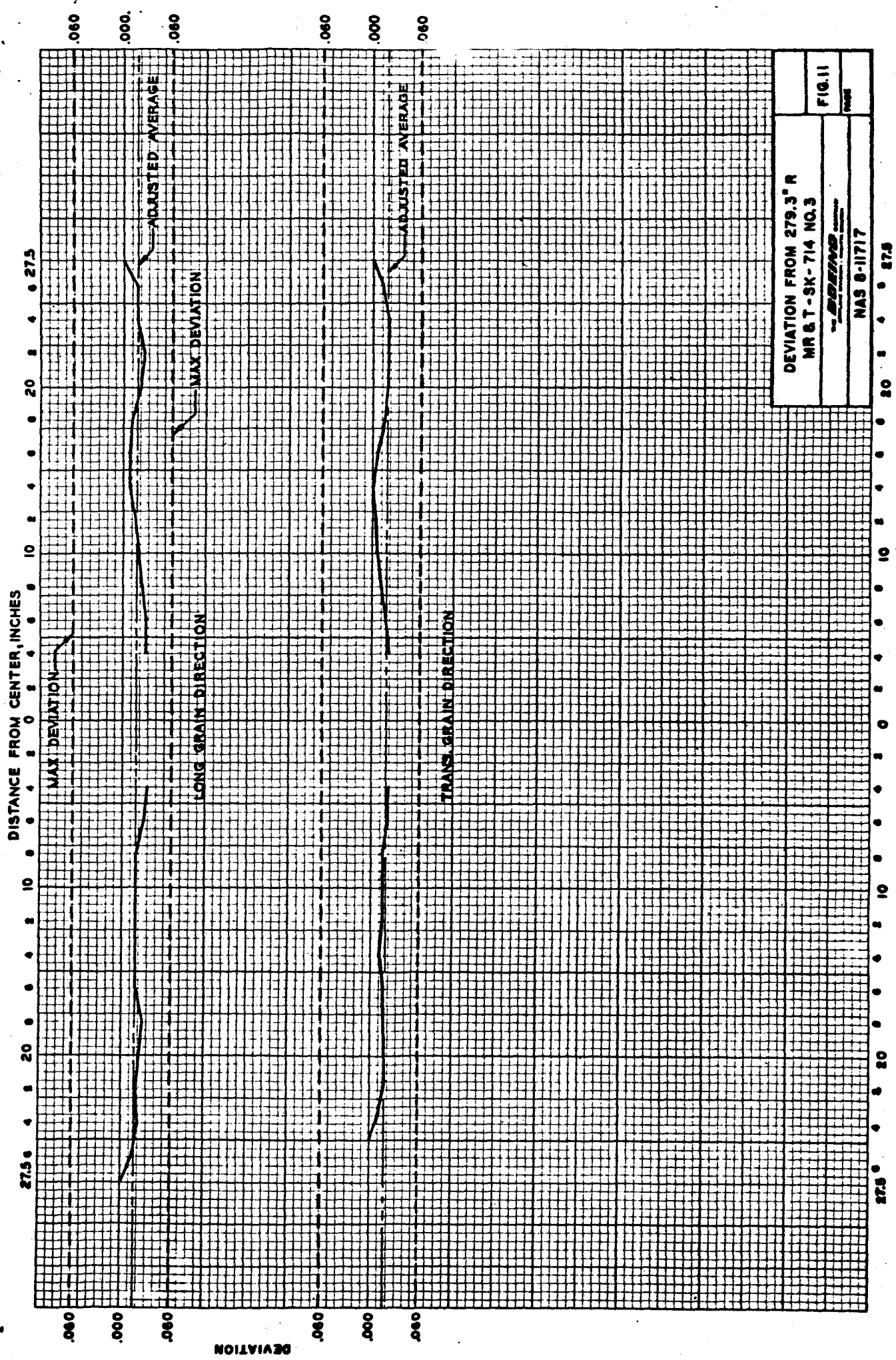


DEVIATION FROM 279.3° R
MR 6-T-SK-714 NO.2

FIG.10

NAS 8-11717

27.5 25 20 15 10 5 0 5 10 15 20 25 27.5



DEVIATION FROM 279.3" R
 MR & T - SK - 714 NO. 3
 -- DISTANCE --
 NAS 8-11717

FIG. 11

Page

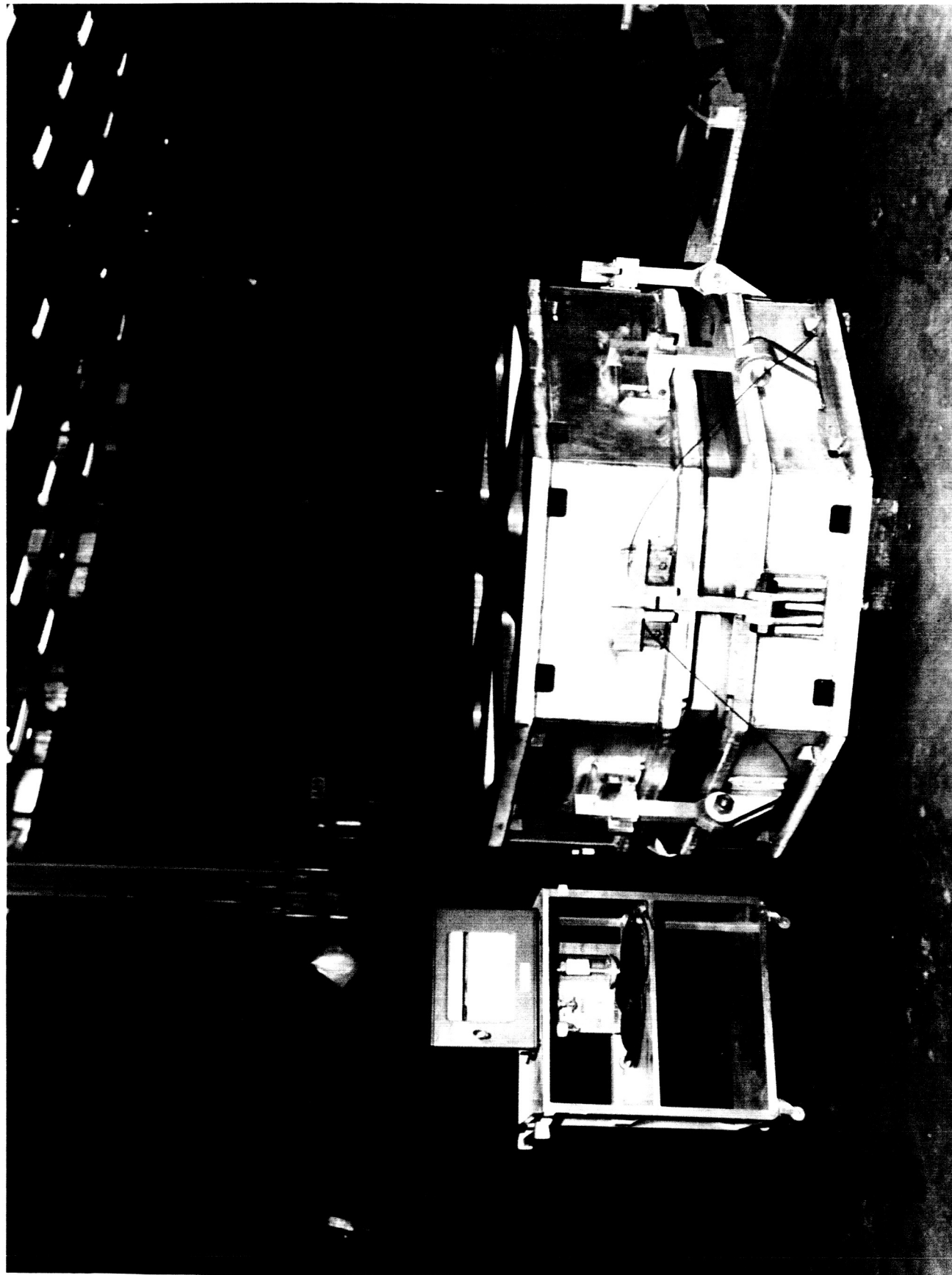


Fig. 12
NAS8-11717

MIT-RSC-MR&T-SK-714 Age Forming Fixture

Proj. 28.43
BWA-69712

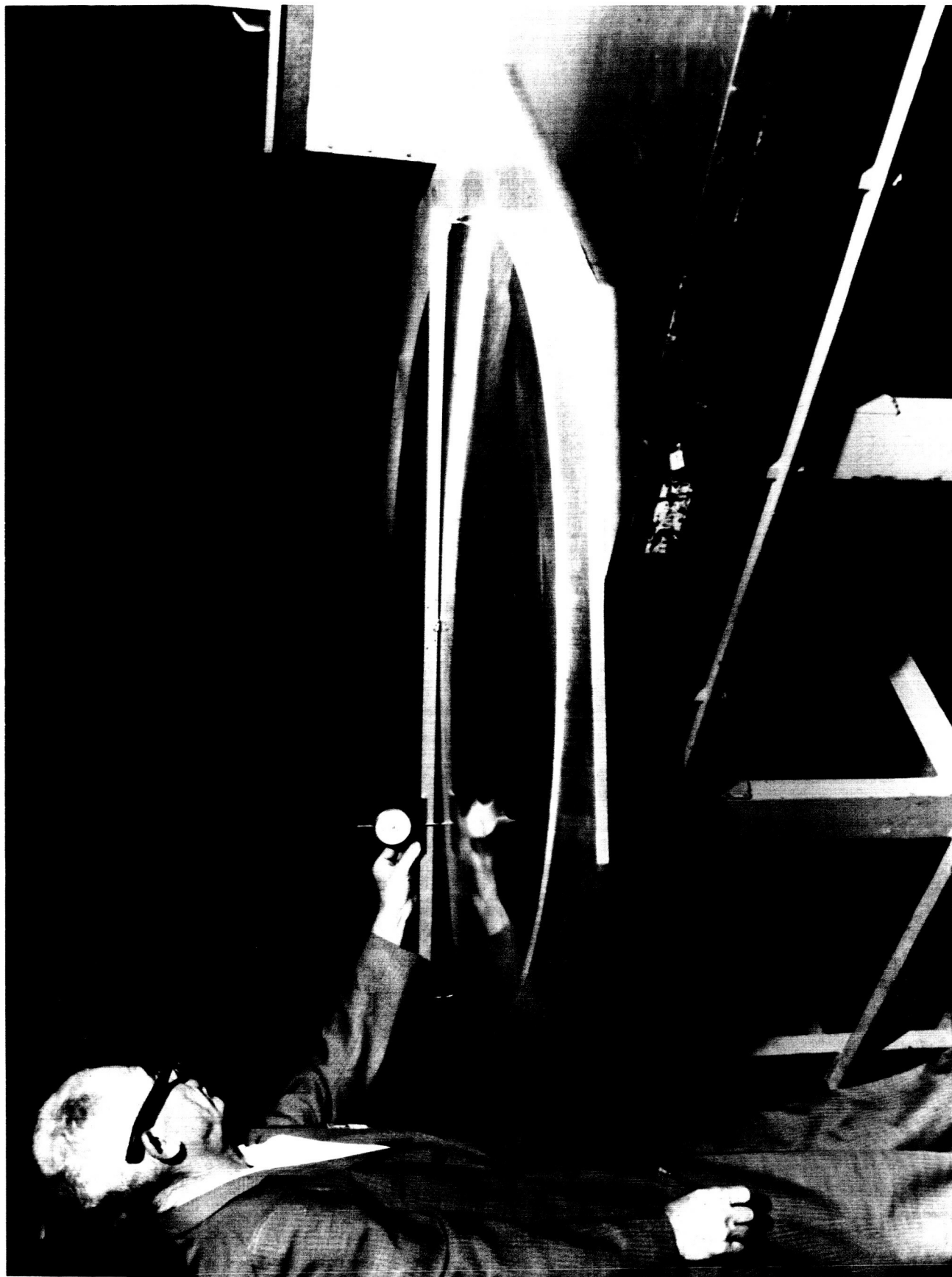


Fig. 13 Measurement With Part Supported on Flat Surface

Proj. 28.43
BWA-69713

NAS8-11717



Fig. 14
NAS8-11717

Curvature Measurement With Blank Supported on
Rubber Pad at Center of Concave Side

Proj. 28.43
BWA-69714



Fig. 15
NAS8-11717

R&D Master In Open Fixture For Forming to 181" Radius Die

Proj. 28.43
BWA-69715

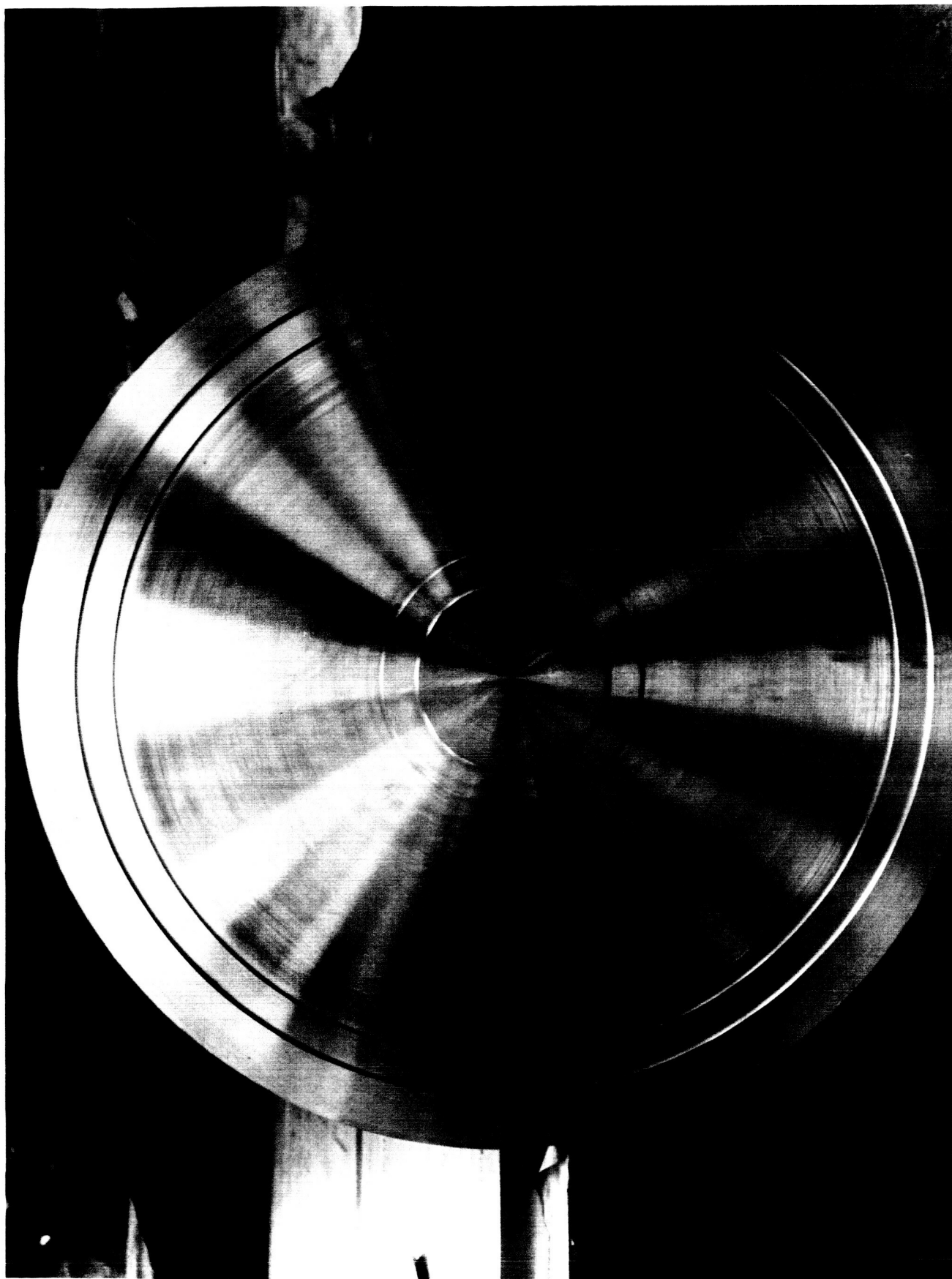


Fig. 16
NAS8-11717

Sculptured MR&T-SK-714 Center Piece Without 8" Diam.
Center Hole - Prior to Age Forming

Proj. 28.43
BWA-69716

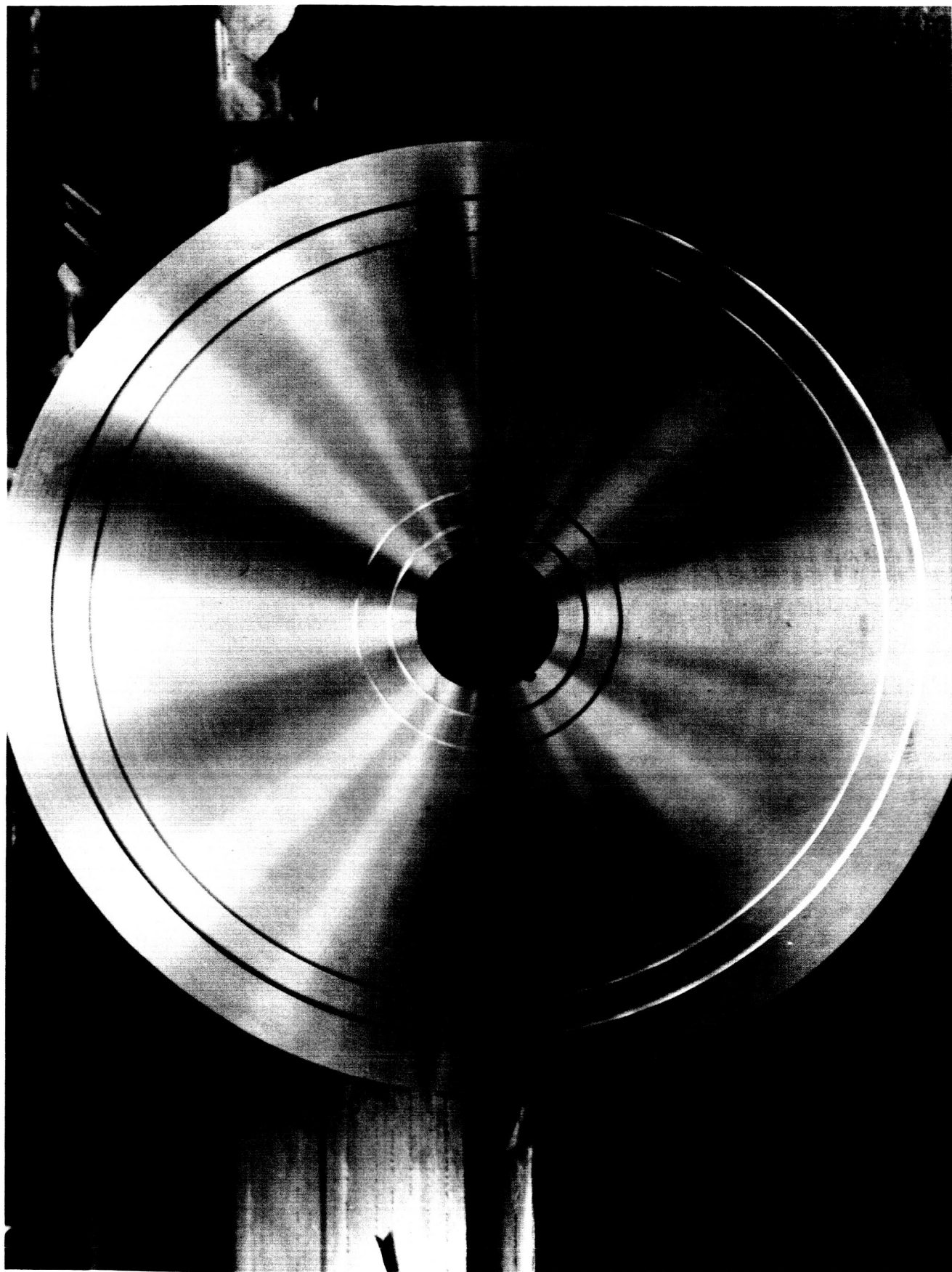


Fig. 17

Sculptured MR&T-SK-714 Center Piece With 8" Diam.
Cutout Prior to Age Forming

Proj. 28.43
BWA-69717

NAS8-11717



Fig. 18
NAS8-11717

R&D Master Reinforced to Hold Developed
Configuration During Plaster Casting

Proj. 28.43
BWA-69718

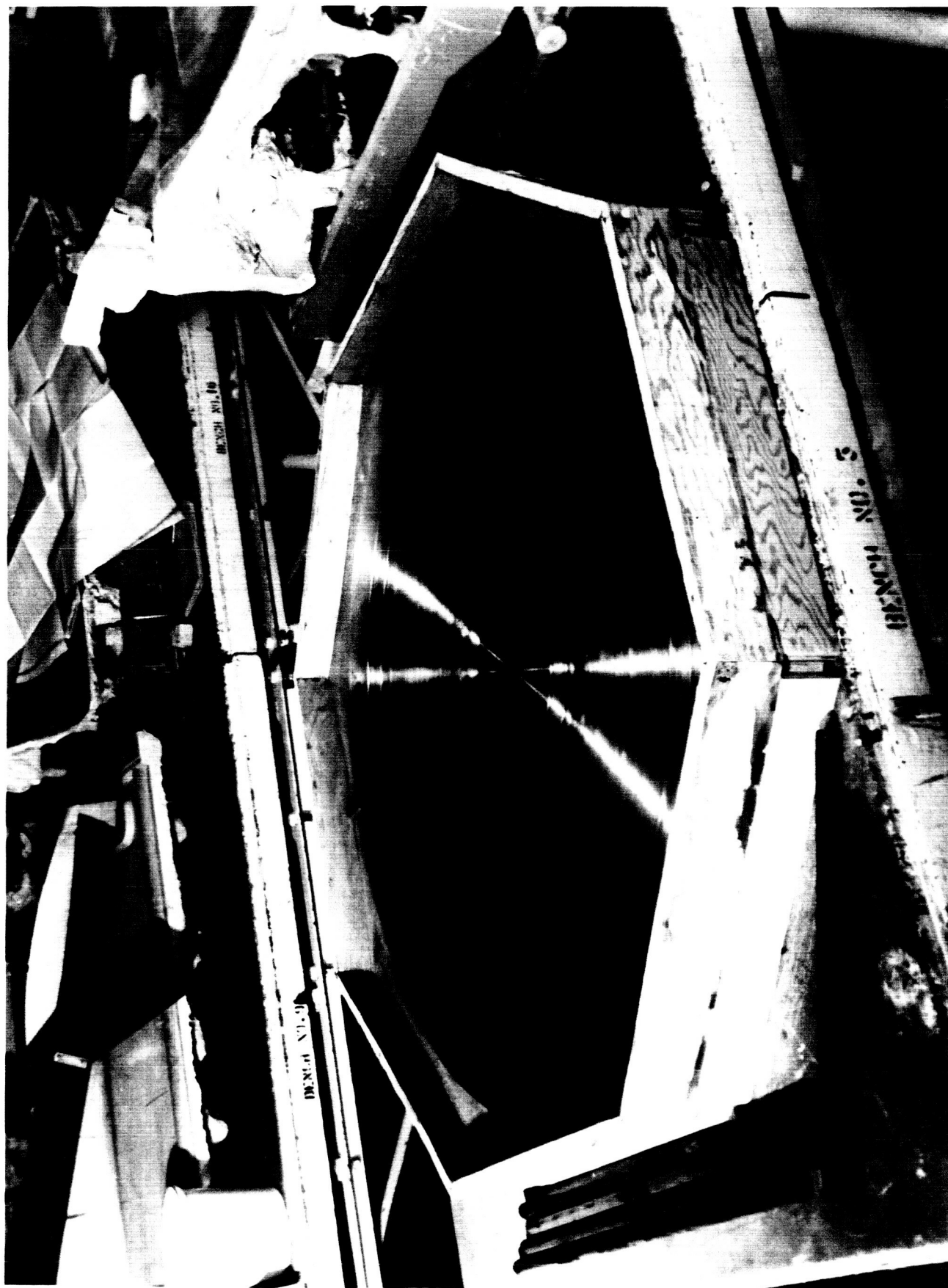


Fig. 19

Plaster Die Pattern & R&D Master Ready for Casting of

Plaster Punch Pattern

Proj. 28.43

BWA-69719

NAS8-11717

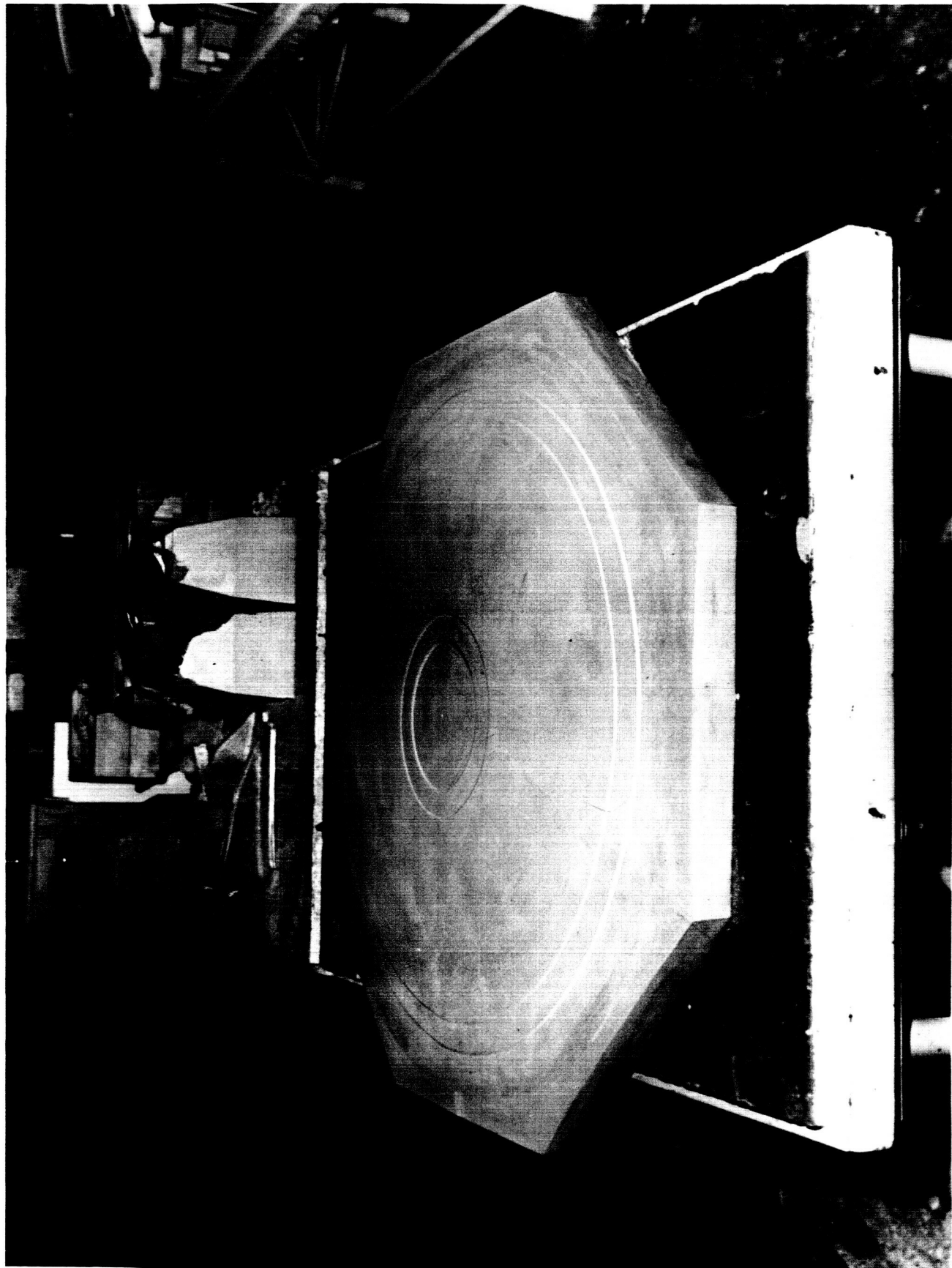


Fig. 20
NAS8-11717

Plaster Punch Pattern

Proj. 28.43
BWA-69720

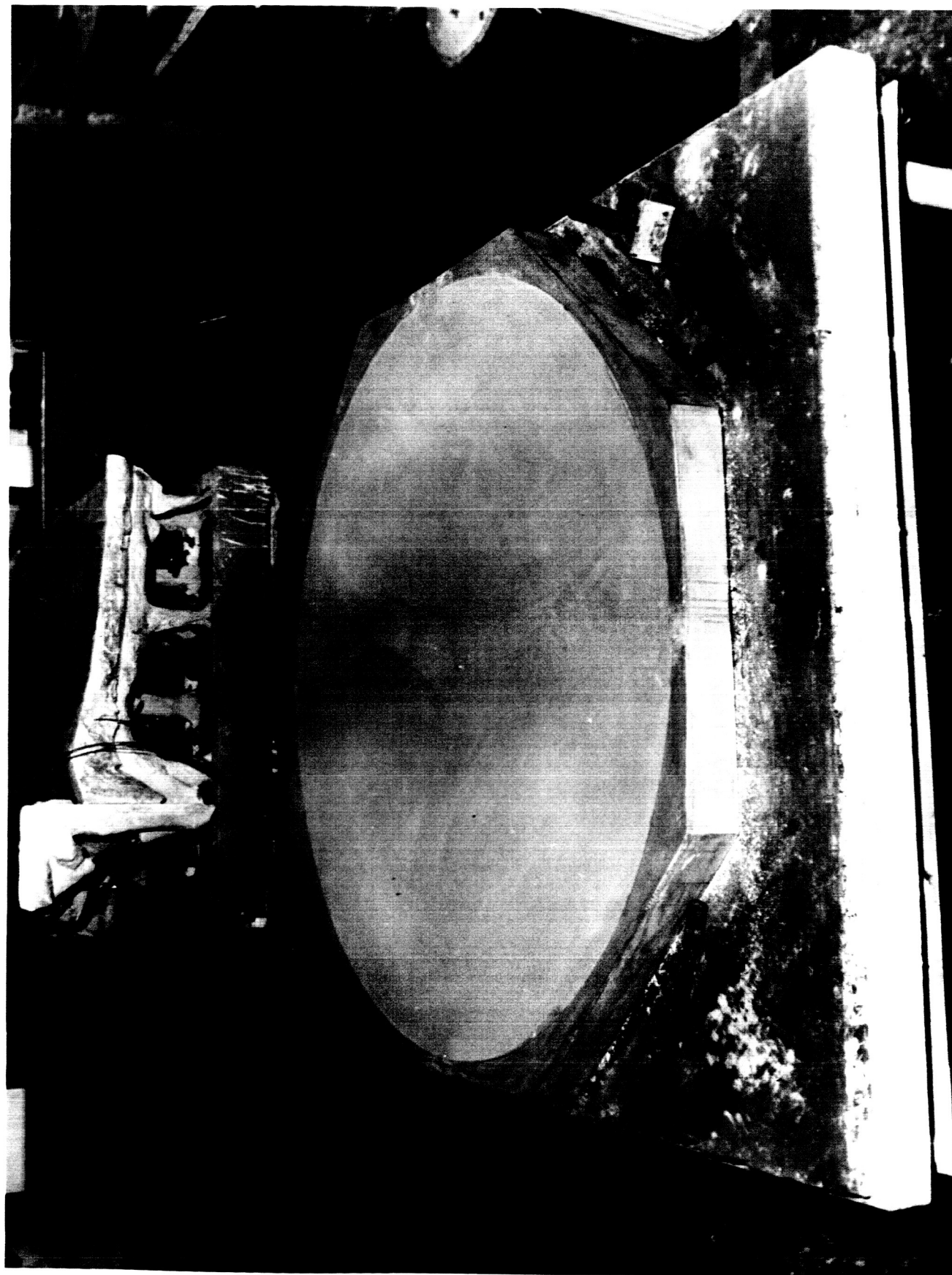


Fig. 21

Plaster Die Pattern

NAS8-11717

Proj. 28.43
BWA-69721

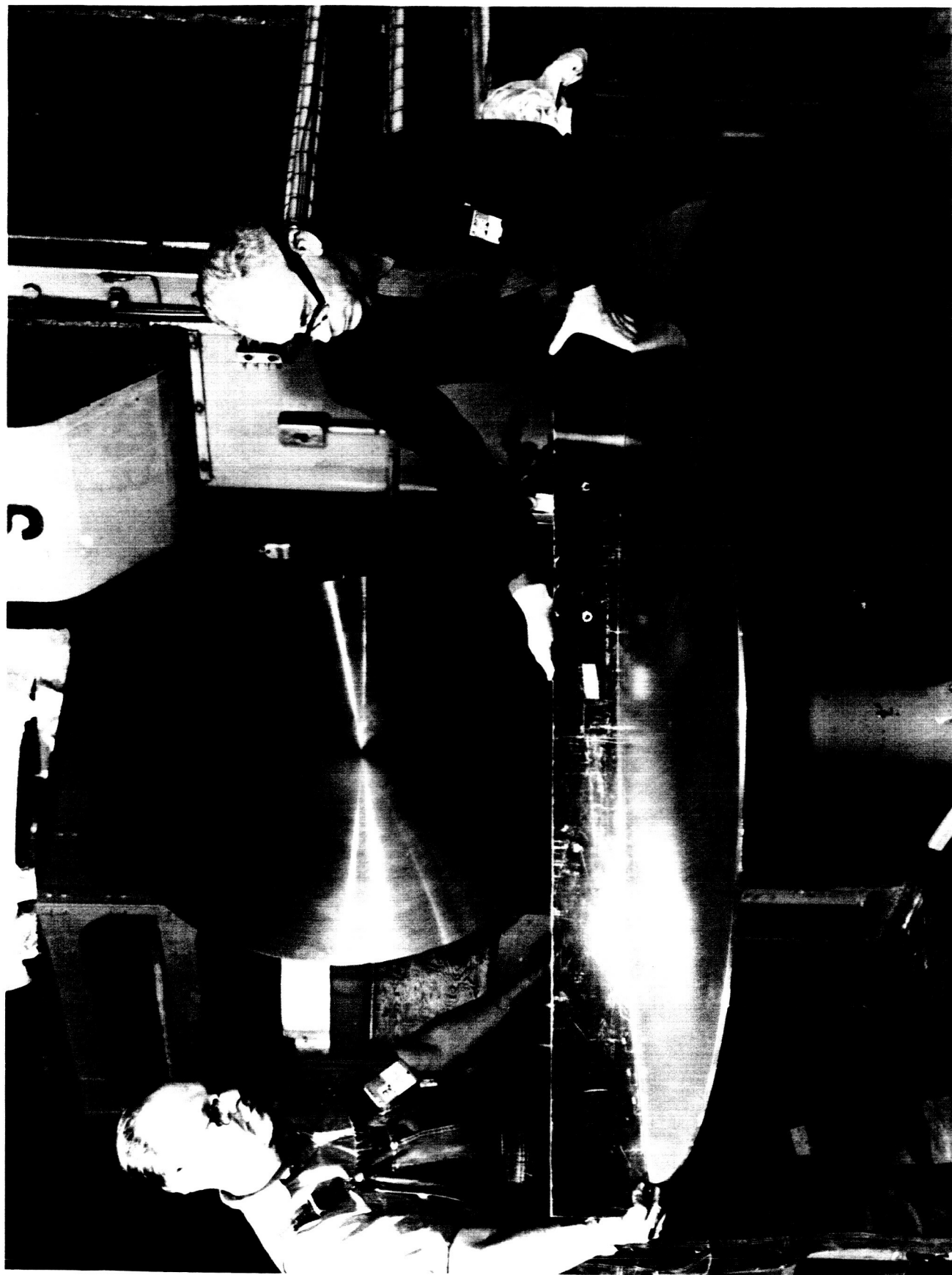


Fig. 22
NAS8-11717

Completed Part Contour Compared to 279.3" Radius Template

Proj. 28.43
BWA-69722

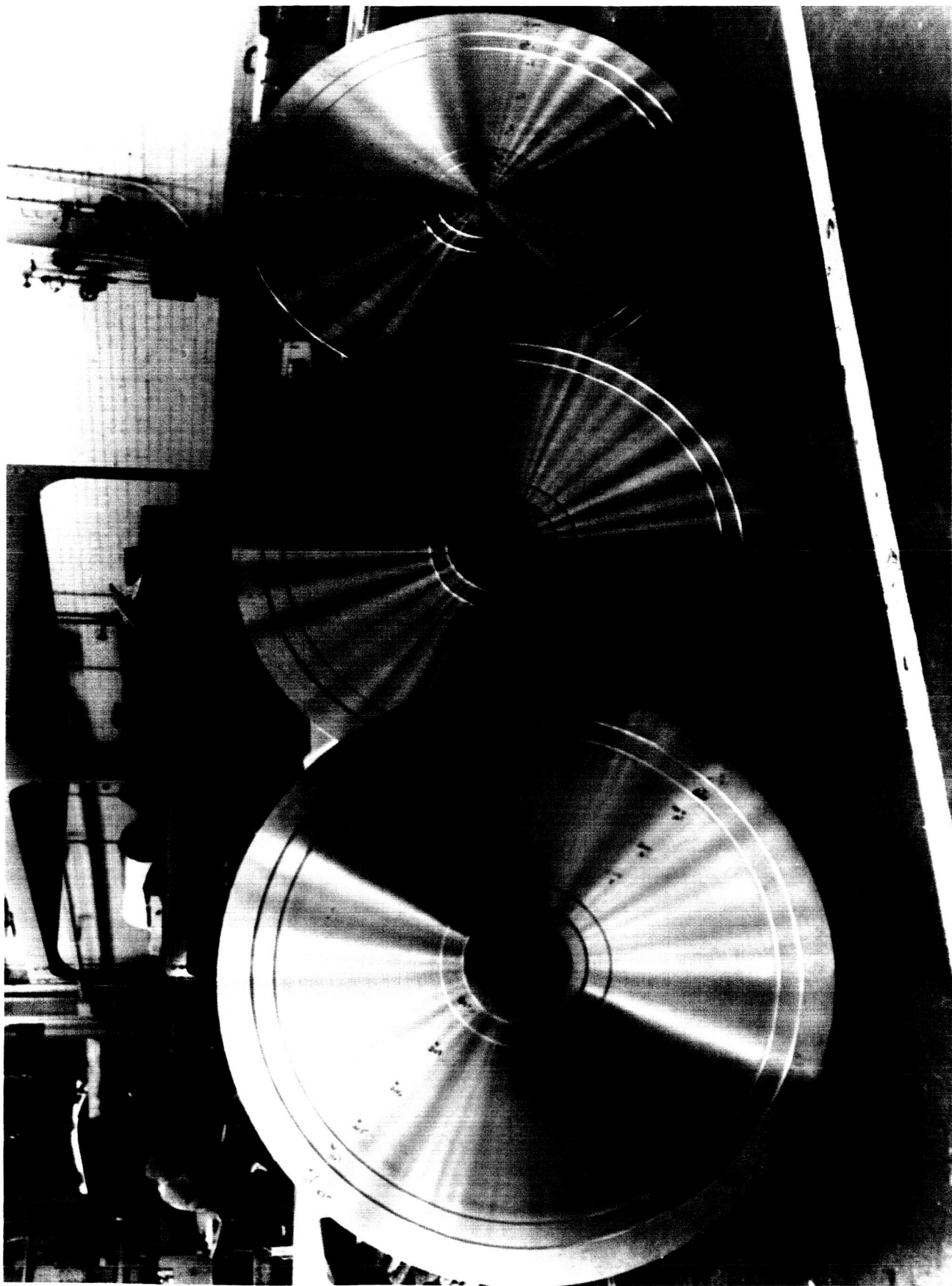


Fig. 23

NAS8-11717

Age Formed MR&T-SK-714 Part Nos. 1, 2, 3

Proj. 28.43
BWA-69723