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THE FABRICATION OF FUEL SUBASSEMBLIES
FOR THE BORAX-III REACTOR

by

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Metallurgy Division

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THE FABRICATION OF FUEL SUBASSEMBLIES FOR THE BORAX III REACTOR

David E. Walker and Robert A. Noland

ABSTRACT

Each Borax-III fuel subassembly consists of a group of aluminum-clad aluminum-uranium alloy fuel plates arranged in an MTR-type array. The fuel plates are electric-resistance spot-welded to two aluminum side-plates and an aluminum central-support plate. An aluminum-0.6 w/o boron, burnable poison strip is attached to each fuel subassembly. The poison strips are made by hot extruding a mixture of aluminum and elemental boron powders in the desired proportions.

FOREWORD

This report describes the fabrication of the fuel subassemblies used in the Borax-III reactor. Responsibility for the project was shared by the Metallurgy Division and the Central Shops Division of Argonne National Laboratory. The former was responsible for all technical phases of the work; the latter performed all production operations. Metallurgy Division personnel (1) developed the manufacturing techniques employed, (2) set up and applied all acceptance and testing criteria, (3) supplied technical liaison with material sources outside the ANL organization, and (4) provided full-time technical supervision over most of the manufacturing operations.

INTRODUCTION

Boiling water reactor experiments (Borax-I and II) conducted at Arco, Idaho, demonstrated the feasibility of a new concept in reactor operation, namely, that existence of boiling at the surface of fuel plates tends to promote self-regulation over a rather broad range of heat flux. The reactor used for these studies employed aluminum, MTR-type brazed subassemblies containing aluminum (1100)-clad aluminum-uranium alloy fuel plates which were made at ORNL. Figure 1 is a schematic illustration of such a subassembly.

As a result of the Borax-I and II tests, a program was undertaken in March 1955 to modify the Borax reactor to produce electrical energy of the order of 2000 kw, enough to provide the town of Arco, Idaho, with complete electrical service. It was desired that the reactor be in operation by July 1955, and that the fuel subassemblies be ready for loading into the reactor by mid-June 1955. This schedule allowed a period of three and one-half months to complete the following:

1. A subassembly design which would permit easy, fast, low-cost fabrication.
2. The development and testing of a suitable subassembly fabrication procedure.
3. Procurement of a large number (over 2000) of aluminum (1100)-clad aluminum-enriched uranium alloy fuel plates from an outside source.
4. Procurement of necessary tooling.
5. Selection of appropriate acceptance tests.
6. Actual fabrication of approximately 90 fuel subassemblies.

The fuel subassembly was to be similar in type to that used in the previous Borax Test Reactors. It was to differ, however, in two ways: the individual fuel elements were to be supported in the transverse direction to protect them from being buckled by rapid discharge of water from the cooling channels; and a burnable poison strip of 0.6 w/o boron-aluminum alloy was to be attached to each fuel subassembly. It was also anticipated that the individual fuel plates might be as long as 48 inches, instead of the 24-inch plates formerly used.

The short time allowed to build the reactor core limited subassembly joining methods to those which would require minimum development. Also, the methods developed had to be capable of being performed on equipment available for use by ANL personnel, such as that used for inert-gas tungsten-arc welding, and electric-resistance spot and seam welding. These limitations made it necessary to eliminate otherwise appropriate joining procedures, such as dip and furnace brazing, from consideration. The choice of a method to fabricate the fuel subassembly was predicated upon the:

1. Length and width of the fuel subassembly.
2. Method of stiffening the fuel plates against buckling.
3. Availability of equipment.
4. Time required to produce a subassembly.
5. Cost per subassembly.

6. Suitability of a given method to be performed by Central Shop personnel (machine shop personnel or the equivalent) without extensive training.
7. Usage of an absolute minimum number of technically trained scientific personnel.

Service requirements of the completed fuel subassembly were not excessively stringent; it was required that the fuel assembly be resistant to corrosion by 220°C, 300 psi water and to the physical stresses imposed upon it during reactor operation for a period of a few months. Any satisfactory service beyond this period was to be considered as somewhat of a bonus. These requirements offered considerable latitude to the fabricator.

PROCEDURE

Fuel Subassembly: Welding Joint Design Development

In order to select the most suitable joint and subassembly design, several all aluminum (1100) subassembly designs were proposed in accordance with the sketches shown in Figures 2 and 3. Trial sections of all but method B were constructed. Each was welded by using resistance spot-welding, resistance seam-welding, and inert-gas tungsten-arc welding, either alone or in combination. The time required for completion and the ease of construction of each was recorded. All units were suitable for use. However, Method D, which involved resistance spot-welding channel-shaped fuel elements to side-plates and a median support plate, required the least cost and time and was selected for use.

By the time the above work was completed, a decision had been made to employ a 30-inch long fuel subassembly made up of 12 pairs of fuel plates, uniformly spaced parallel to each other, as shown in Figure 4. Twenty-two of the fuel plates were to be 1.841 in. wide x 26.8 in. long; the two top plates to be 1.841 in. wide x 29.8 in. long. Each fuel plate was to be spot welded every 3/4 in. along its length to a 0.062-in. thick side strip on one side, and to a median supporting strip of the same thickness on the other. Fuel plate cladding, median supporting strip, and side strips were specified to be 1100 aluminum. A 0.6 w/o boron, aluminum-nickel-boron plate, 0.020 in. thick x 3.828 wide x 29.1 long, was to be inert-gas tungsten-arc tack welded to the outer face of one of the side strips. Working drawings which fully describe the subassembly and its components are included in the Appendix.

It should be noted that water channel requirements fixed the distance between fuel plates to 0.264 in. This dimension made it necessary to limit the welding flange width to 0.204 in. to allow for local upsetting at the spot

weld sites, which would otherwise have interfered with assembly. Thus the flange width was less than half of the 0.480 in. suggested by accepted resistance-welding joint-design practice for single interface joints between two 0.060-in. thick sheets.⁽¹⁾ The double interface joint at the median-strip (Figure 3 - Detail II) represented an even greater deviation from accepted practice. Unfortunately, it was not possible to increase flange width without seriously adding to manufacturing cost; thus the acceptance of conditions spawned by the narrow flange was mandatory. Some of these were the periodic occurrence of weld metal expulsion; a slight lowering of mechanical properties; extensive metal pick-up of the welding electrodes; and the need for extremely close control over welding machine set-up, power settings, and operating performance.

Fuel Plates; Fabrication

Aluminum-clad aluminum-uranium alloy fuel plates of two core compositions were obtained from Metals and Controls Corp., Attleboro, Massachusetts. The cores of these plates contained 12 and 19 w/o, respectively, of highly enriched uranium. These plates were produced by hot roll bonding 1100 aluminum cladding to the aluminum-uranium alloy core picture-framed with 1100 aluminum, using techniques similar to those developed at ORNL.⁽²⁾ After the bonding passes were made, the plates were coated with aluminum brazing flux and heated at 595° C for one hour as a test of bond integrity (at Metals and Controls Corp.). The presence of unbonded areas was revealed by blistering of the clad, which could be observed by visual examination. Acceptable plates were then cold rolled to final thickness. Final length and width dimensions were obtained by shearing the plates after core location by radiography.

Upon arriving at ANL, the plates were inspected as follows:

Visual Inspection; Fuel Plates

All plates were examined for surface defects such as laps, seams, embedded foreign matter, and heavy scratches. Generally, the presence of any one of the listed defects was reason for rejection, because no information based either upon performance in a reactor or destructive testing was available to provide other basis for decision. Of approximately 2650 plates examined, 473 were rejected, most of them for embedded matter and heavy scratches.

Radiographic Inspection; Fuel Plates

The central location of the core was affirmed by radiographic examination. A 100% radiographic inspection was made of the first 150 plates. The number X-rayed was reduced to 10% after it was found that all of the first group of plates examined were acceptable. No plates were rejected

because of core dimensions or geometry. Some camber was observed in the core, but it was not enough to cause rejection. A group of plates where the core had the greatest camber, approximately $3/32$ in., were die formed and re-examined. In no case did the core edge become part of the formed flange, and no fractures at this point were observed.

Bond Testing; Fuel Plates^(a)

The bond was determined under water by ultrasonic transmission⁽³⁾ wherein a signal generated by a quartz crystal is transmitted through a bonded plate and picked up by a quartz receiver on the other side. Changes in the energy received are a result of changes in transmission through the plate and can be correlated with the cause by destructive testing of the plate in question. A permanent record was obtained by recording on a Brush oscillographic recorder the signal received.

The entire area of each of the first 51 plates received was fully tested to determine the degree of consistency of the manufacturing process. After this work had shown the process to be fairly consistent, the remainder of the plates were tested for aluminum-to-aluminum bond at all four edges, and for clad-to-core bond along a $3/16$ -in. wide zone along the longitudinal center line. Periodically plates so examined were selected at random and subjected to the 100% interrogation given the first group. All plates tested were identified by an etched number at one end. A suffix number, i.e., 1, 2, 3, 4, was added to all plates after plate number 998.

Of a total of 2709 items tested, 3 were rejected because of lack of bond and because of cracks in the bonding layer. One of these had a large unbonded area which extended to the sheared edge. It is believed that this plate passed the blister test at Metals and Controls because, as it was unbonded to an open edge, no internal pressure sufficient to raise a blister was possible.

It was found that bonds of a lower order were present in plates 836 through 846, but that there was no evidence of complete lack of bond. Fifty per cent of the plates between the numbers 61 and 1197 appeared to have poorer bonds at the plate end which was numbered. A decrease in bond strength at the end opposite the number was found in 15% of the plates between Nos. 1200 to 3200. From plates 4000 to 7600 the areas of lower sonic transmission appeared random.

Subassembly Components; Fabrication

The side and center plates were obtained by shearing 0.062-in. thick 1100 aluminum sheet stock to the required length and width dimensions. The fuel plates were formed into the flanged channel section required for

(a) Results and procedure by W. N. Beck, ANL Metallurgy Division.

assembly by means of a punch and die, which is shown schematically in cross section in Figure 5. Drawings number RE-1-15520-C and RE-1-15521-C in the Appendix describe the flanged plates produced with this punch and die. Earlier attempts to flange the fuel plate by means of a press brake were not successful because required dimensional tolerances could not consistently be obtained.

Assembly and Welding

The subassembly was constructed by assembling a double row of fuel plates to the aluminum side and center-plates and spot welding them in place, as shown schematically in Figure 6. Successive double rows of fuel plates were then added until the full 24-plate subassembly was complete. The required plate spacing (0.264 in.) was obtained by placing 0.264-in. thick cloth-filled phenolic-plastic (Micarta) spacer strips between the previously welded row of fuel plates and the next unwelded row. This assembly, with spacers in place, was held firmly in position for welding by means of specially designed non-conducting clamps, as shown in Figure 7. After the welding of each double row of fuel plates was completed, the spacing strips were removed and used to space the next double row of plates to be welded. In welding the plates in place, spot tack welds were first made at the ends and at 6-in. intervals along the length of each fuel plate (Figure 8). The clamps were removed, and welds were made between each of the tack welds, so as to locate the welds 3 in. apart. The third welding pass placed welds between the 3-in. spaced group, to give welds $1\frac{1}{2}$ in. apart. On the final weld pass the spacing was again split in half so that the desired final weld spot spacing of $\frac{3}{4}$ in. was obtained. To guide the welding machine operator who manipulated the work by hand, weldspot spacings were scribed on the side plates prior to assembly. In each row of welds, the welds were offset longitudinally approximately $\frac{1}{2}$ in. to the welds in the adjoining plates.

Shunting of the welding power occurred as a result of the proximity of the welds. Thus, higher welding power was required on welds in the same row which were spaced closer than 3 in. Typical conditions used are listed below:

<u>Machine Type</u>	Sciaky Bros. Inc., 3-phase, 75 kva, Press Type Spot Welder
---------------------	---

<u>No. of Impulses</u>	Single
------------------------	--------

<u>Welding Pressure</u>	283 lb. - constant low
-------------------------	------------------------

Heat (Cycles)	4
---------------	---

Cool (Cycles)	2
---------------	---

Power Settings (Phase Shift)

<u>Spacing</u>	<u>Single Interface</u>	<u>Double Interface</u>
3 in.	50	53
1- $\frac{1}{2}$ in.	51	55
3/4 in.	52	56

Welding Electrodes - Material and Design

The electrodes were offset and were internally water cooled. Electrode tips were made of Mallory alloy 100 because of its excellent resistance to deformation. The design of the electrode tip was found to be especially critical to the quality of the welds and the rate at which welds could be made. Especially important was the welding face contour which directly affected the rate at which the electrode surface picked up aluminum, an undesirable phenomenon. Face contour also had a direct effect on the location of the weld in the joint flange; location of the weld as close to the center of the flange as possible was mandatory to minimize expulsion of the weld metal. When excessive expulsion occurred, the resultant welds were low in strength. Also, during expulsion the aluminum collapsed, so that motion between the electrode face and the aluminum flange took place. This caused the aluminum to wipe across the electrode, accelerating the incidence and rate of pick-up. After a series of experiments it was shown that the optimum tip contour was a segment of a sphere of 6-in. radius.

Space limitations imposed by the weld joint geometry made it necessary to use off-set electrodes a type which invariably deflect when mechanically loaded during the welding operation. Because of this deflection it was found necessary to machine the spherical face of the electrode to locate the geometric center of the sphere forward of the center of the electrode (Figure 9), so that the point of maximum current flow (tangency) at welding pressures occurred at the center of the plate flange.

To reduce the time that the welder was out of operation because of electrode replacement, multi-faced electrodes in the shape of a modified wheel were developed (Figure 10). By this means six welding faces, each machined to the spherical contour previously described, were available for use. When excessive metal pickup occurred, it was necessary only to rotate the electrodes so that a pair of clean faces were in the welding position. When in place, the electrodes were bolted at their centers to rectangular copper bars which were fastened to the top and bottom arms of the welder. The front face of each electrode was recessed to accommodate a plastic liner which prevented contact with the fuel plate at this point.

Electrode Pick-up

Metal pick-up on the electrode was severe; thus cleaning of the electrode faces or turning of the electrodes to put a new face into position was frequently required. An effort was made to reduce metal pick-up by electroplating the electrodes with metals such as gold, silver, nickel and rhodium. This was done to reduce contact resistance (gold or silver) or to provide a metal with less tendency to alloy with aluminum (nickel or rhodium). No significant improvement was noted, although some reduction in electrode pick-up was obtained with a combination of gold and rhodium. The amount of gain, however, was not considered sufficient to warrant its use. The presence of oxide on the aluminum surfaces appeared to be an aid in reducing metal pick-up, thus cleaning before welding consisted solely of vapor degreasing in trichlorethylene.

Testing the Welds

No satisfactory procedures were developed for non-destructively testing the welds on actual fuel subassemblies. However, destructive tests were made on a number of aluminum (1100) facsimile subassemblies. Also, free bend tests were performed on welded aluminum samples having the same configuration as the actual units. Although the results indicated that the welds were not of aircraft quality, their mechanical properties were judged to be sufficient to provide adequate protection against failure in operation for the period desired. Figure 11 shows a typical bend-test sample that reveals acceptable welds; that is, welds capable of withstanding 90° unrestrained bending without fracturing through the weld interfaces. As a process control procedure and to assure weld uniformity, bend-test samples were run at three evenly spaced intervals during each shift.

Aluminum-Boron Consumable Poison Strips

Core reactivity was to be adjusted to compensate for fuel burn out with boron (B^{10}). The boron (as natural B) was supplied by an aluminum-1.0 w/o nickel - 0.6 w/o boron strip, 0.020 in. thick x 3.828 in. wide x 29.8 in. long, which was inert-gas tungsten-arc welded to the outer face of one side plate of each completed subassembly. Addition of nickel (1 w/o) to the material was done to improve its corrosion resistance to the reactor coolant.

The strips were made by hot extruding an uncompacted aluminum-canned mixture of metal powders into an oversized plate which was subsequently rolled to final thickness and sheared to size. The process sequence was as follows:

1. Weigh appropriate amounts of aluminum, elemental boron and nickel powders to give 0.6 w/o boron, 1.0 w/o nickel, and 98.4 w/o aluminum.

2. Ball mill (dry) powders for 15 hours to form homogeneous mixture.
3. Load powder mixture in 1/8 in. wall x 8 in. O.D. x 16 in. long extrusion cans, as shown in Figure 12. Mount can on a platform fitted with a syntron vibrator to permit charge to be vibrated to improve packing density.
4. Weld end cap in place.
5. Evacuate can with roughing pump.
6. Seal evacuation tube.
7. Heat to 500° C.
8. Extrude into plate - 3/8 in. thick x 4 in. wide x approximately 25 ft. long. Use shear type die. (Extrusion was done on a 1500-ton horizontal press by Precision Extrusions, Inc., Bensenville, Illinois.)
9. Crop section of extrusion at ends having heavy cladding and/or extrusion defects due to inverse flow.
10. Cut 2-1/4 to 2-1/2-in. strips from the 4 in. wide extrusion.
11. At 600° C cross roll from 4 in. to 4-3/8 in.
12. Hot roll (600° C) into sheet approximately 4-1/2 in. wide x 14 in. long x 0.042 in. thick, using reductions of the order of 30% per pass.
13. Finish roll from 0.042 in. to 0.020 in. without reheating.
14. Anneal at 500° C for 60 minutes. Clamp work between flat steel plates during annealing (to flatten).
15. Shear to final size.

Handling of the powder mixture before extrusion was simplified considerably by containing it within the aluminum can. It was thus inevitable that the final extrusion was clad with aluminum supplied by the can. Although the thickness of this cladding was fairly heavy at the ends of the extrusion, the cladding on the remainder was thin and suitably uniform. The ends, therefore, were cropped, and the central section, approximately 80% of the total length, was rolled into 0.020-in. sheet. Because the cladding of the as-extruded section was not removed, a 0.001 to 0.0015-in. thick cladding was present on the finished strip.

The material in the as-extruded condition is soft and ductile. Tests performed on representative samples show the properties of the material to be as follows:

Ultimate Tensile Strength	19000 to 20000 psi.
% Elongation (2 in.)	25 to 30
Brinell Hardness	88
Density (g/cc)	2.73

A photomicrograph showing the microstructure of a typical as-extruded section of the alloy is shown in Figure 13.

Homogeneity in the finished material was good, as indicated by frequent chemical analyses which were made at spaced intervals along the length of each extrusion. A representative group of analyses taken from a typical extrusion is as follows:

<u>Distance from Butt (in.)</u>	<u>w/o Boron</u>	<u>w/o Nickel</u>
27	0.51	0.93
144	0.56	0.97
288	0.56	1.00

A small number of samples of the alloy were corrosion tested at 290°C in distilled, de-ionized water for one week. The physical appearance of the samples indicated their corrosion resistance to be superior to that of 1100 aluminum, and of the order of that which would be expected from cast and wrought aluminum - 1.0 w/o nickel alloys (Alcoa M-388).

Fuel Assembly

To incorporate the fuel subassemblies into complete fuel assemblies ready for use, Shops personnel plug welded (inert-gas tungsten-arc) cast-aluminum (356 alloy) end fittings to each subassembly and mechanically attached a stainless steel handle to the top fitting of each as shown in Drawing No. RE-1-15318-D in the Appendix. Drawings No. RE-1-15319-D, RE-1-15320-C, and RE-1-15321-C, also in the Appendix, describe the handle and end fittings.

ACKNOWLEDGEMENTS

In the course of this project the authors received help and suggestions from many individuals to whom we owe our gratitude. Among those to whom we are especially grateful are:

- (1) The men in the Central Shops group who carried out the production operations;
- (2) H. V. Ross (Supt.) and A. A. Denst (Asst. Supt.) of the Shops for their willing co-operation and executive support;
- (3) F. G. Foote, Director, ANL Metallurgy Division, upon whose suggestion was based the final design for the median supporting strip;
- (4) W. J. McGonnagle, W. N. Beck, and S. Matras of the ANL Metallurgy Division;
- (5) W. J. Farrell and A. Schiario of Sciaky Bros., Inc., Chicago, Illinois.

REFERENCES

1. "Welding and Brazing Alcoa Aluminum", p. 90, Alum. Co. America, (1948).
2. J. E. Cunningham and E. J. Boyle; Vol. IX, Paper 953, Reactor Technology and Chem. Processing, Proceedings of the International Conference on Peaceful Uses of Atomic Energy, United Nations, 1956.
3. W. N. Beck; "An Ultrasonic Scanner and Recording System", Nondestructive Testing, 15(1) 42-3 (1957)

FIGURE 1
CROSS SECTION: BRAZED ASSEMBLY

FIGURE 2
JOINT DESIGNS IN TRIAL SAMPLES

METHOD A

METHOD B

DETAIL I

DETAIL II

FIGURE 3
JOINT DESIGNS IN TRIAL SAMPLES

FIGURE 4
BORAX III FUEL SUBASSEMBLY

FIGURE 5
FUEL PLATE FORMING DIE (SCHEMATIC)

FIGURE 6
ASSEMBLY METHOD (SCHEMATIC)

FIGURE 7
SUBASSEMBLY CLAMPING DEVICE

FIGURE 8
SUBASSEMBLY WELDING IN PROCESS

FIGURE 9
EFFECT OF WELDING PRESSURE ON ELECTRODE
DEFLECTION (SCHEMATIC)

FIGURE 10
MODIFIED WHEEL-TYPE WELDING-ELECTRODE

FIGURE 11
SPOT WELDED BEND TEST SAMPLE

FIGURE 12
CAN FOR EXTRUSION OF METAL POWDERS

FIGURE 13
MICROSTRUCTURE OF Al-1w/o Ni-0.6 w/o B
POWDER MIXTURE AFTER EXTRUSION

MICRO NO. 21285

500 x

SURFACE - AS POLISHED

APPENDIX

1.	RE-1-15318-D	Borax III Element Assembly
2.	RE-1-15319-B	Handle
3.	RE-1-15320-C	Top Fitting
4.	RE-1-15321-C	Bottom Fitting
5.	RE-1-15322-C	Central Unit Subassembly
6.	RE-1-15323-C	Standard Plate
7.	RE-1-15324-C	Outer Plate
8.	RE-1-15325-C	Center Plate
9.	RE-1-15326-C	Side Plate
10.	RE-1-15520-C	Formed Standard Plate
11.	RE-1-15521-C	Formed Outer Plate

DRWG. NO.
RE-1-15319-B

MICRO-FILM STAMP										RE-1-18167-D		1	
										RE-1-15318-D		1	
										NEXT ASSEMBLY		NO. REQUIRED	
										ARGONNE NATIONAL LABORATORY		THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY	
										TITLE		HANDLE	
										SCALE		DRWG. NO.	
										FULL		RE-1-15319-B	

APPROVED CONST.	DATE	CHIEF DRAFTSMAN	DATE
<i>[Signature]</i>	10/4/52	<i>[Signature]</i>	3/1/55
STAFF APPROVAL	DATE	CHECKED	DATE
<i>[Signature]</i>	5/1/52	<i>[Signature]</i>	3/17/55
REPRESENTATIVE	GROUP	DRAWN BY	DATE
ZINN	BOGORAD	GIORGIS	3-14-55
TOLERANCES UNLESS OTHERWISE NOTED FRACTIONAL $\pm$ $\frac{1}{16}$, DECIMAL $\pm$.005, ANGLE $\pm$ $\frac{1}{4}^\circ$ REMOVE ALL BURRS			
MATERIAL			
SST. #304			

SYM. ZONE	CHANGE	DATE	BY	CHK.

DRAWG. NO.

RE-1-15903-D		1
RE-1-15318-D		1
NEXT ASSEMBLY		NO. REQUIRED
ARGONNE NATIONAL LABORATORY THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY		
TITLE		
TOP FITTING		
SCALE	DRWG. NO.	
FULL	RE-1-15320-C	

DRWG. No.
RE-1-15322-C

MICRO-FILM STAMP										RE-1-15318-D		1	
APPROVED CONST.		DATE		CHIEF DRAFTER		DATE		NEXT ASSEMBLY		NO. REQUIRED			
STAFF APPROVAL				CHECKED		DATE		ARGONNE NATIONAL LABORATORY		THIS DRAWING IS THE PROPERTY OF			
REPRESENTATIVE		GROUP		DRAWN BY		DATE		THE ARGONNE NATIONAL LABORATORY		TITLE			
ZINN		BROOKS		GEORGE		3-1-55		CENTRAL UNIT SUBASSY.					
TOLERANCES UNLESS OTHERWISE NOTED													
FRACTIONAL ± 1/16, DECIMAL ± .005, ANGLE ± 1/4°													
REMOVE ALL BURRS													
MATERIAL								SCALE		DRWG. NO.			
SEE RE-1-15318-BM								FULL		RE-1-15322-C			

RE-1-15323-C

SCALE - 8=1

SECTION AA

MICRO-FILM STAMP

SYM.	ZONE	CHANGE	DATE	BY	CHK.

APPROVED CONST.	DATE	CHIEF DRAFTER	DATE
STAFF APPROVAL		CHECKED	
REPRESENTATIVE		GROUP	

TOLERANCES UNLESS OTHERWISE NOTED
FRACTIONAL $\pm$ $\frac{1}{16}$, DECIMAL $\pm$.005, ANGLE $\pm$ $\frac{1}{4}^\circ$
REMOVE ALL BURRS

MATERIAL
AS REQUESTED

RE-1-15520-C	1
NEXT ASSEMBLY	NO. REQUIRED
ARGONNE NATIONAL LABORATORY	THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY
TITLE	
STANDARD PLATE	
SCALE	DRWG. NO.
FULL & NOTED	RE-1-15323-C

CAMBER OF CORE NOT TO EXCEED .030

SCALE - 8=1

SECTION AA

RE-1-15324-C

DRAW. NO.

RE-1-15321-C		1	
NEXT ASSEMBLY		NO. REQUIRED	
ARGONNE NATIONAL LABORATORY		THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY	
TITLE		OUTER PLATE	
SCALE		FULL 1	
NOTED		RE-1-15324-C	

APPROVED CORL:	DATE	CHIEF DRAFTSMAN	DATE
STAFF APPROVAL:	3-21-55	W. H. K.	3-21-55
DESIGNED BY:	GROUP	DATE BY	
ZINN	3-21-55	3-10-55	
TOLERANCES UNLESS OTHERWISE NOTED			
FRACTIONAL ± .01 DECIMAL ± .005 ANGLE ± 1/4°			
REMOVE ALL DIMENSIONS			
MATERIAL			
AS REQUESTED			
SYN. JUNE	CHANGE	DATE	BY

MICROFILM STAMP

RE-1-15325-C

MICRO-FILM STAMP

SYM.	ZONE	CHANGE	DATE	BY	CHK.

APPROVED CONST.	DATE	CHIEF DRAFTSMAN	DATE
STAFF APPROVAL		CHECKED	3/1/55
REPRESENTATIVE	GROUP	DRAWN BY	
ZINN	BORGARD	GEORGIS	3-11-55
TOLERANCES UNLESS OTHERWISE NOTED			
FRACTIONAL $\pm \frac{1}{16}$, DECIMAL $\pm .005$, ANGLE $\pm \frac{1}{4}^\circ$			
REMOVE ALL BURRS			
MATERIAL			
2S ALUMINUM			

RE-1-15904-D	1
RE-1-15322-C	1
NEXT ASSEMBLY	NO. REQUIRED
ARGONNE NATIONAL LABORATORY	
THIS DRAWING IS THE PROPERTY OF	
THE ARGONNE NATIONAL LABORATORY	
TITLE	
CENTER PLATE	
SCALE	DRWG. NO.
FULL	RE-1-15325-C

RE-1-15326-C

MICRO-FILM STAMP		APPROVED CONST.		DATE	CHIEF DRAFTER	DATE	RE-1-15904-D	2
		STAFF APPROVAL			CHECKED	DATE	RE-1-15322-C	2
		REPRESENTATIVE		GROUP	DRAWN BY	DATE	NEXT ASSEMBLY NO. REQUIRED	
		ZINJ		30602	GIORGIS	3-11-55	2	
		TOLERANCES UNLESS OTHERWISE NOTED						ARGONNE NATIONAL LABORATORY THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY
		FRACTIONAL ± 1/16, DECIMAL ± .004, ANGLE ± 1/2°						
		REMOVE ALL BURRS						
		MATERIAL		SCALE		TITLE		
		2 S ALUMINUM		FULL		SIDE PLATE		
		DATE BY CHK.		DRWG. NO.		RE-1-15326-C

[illegible]

DRWG. NO. RE-1-15521-C

MICRO-FILM STAMP				APPROVED CONST.	DATE	CHIEF DRAFTSMAN	DATE	RE-1-15322-C	2
				STAFF APPROVAL		CHECKED	DATE	NEXT ASSEMBLY	NO. REQUIRED
				REPRESENTATIVE		GROUP	DATE	ARGONNE NATIONAL LABORATORY	
				ZINN		BOGARD	DATE	THIS DRAWING IS THE PROPERTY OF THE ARGONNE NATIONAL LABORATORY	
				TOLERANCES UNLESS OTHERWISE NOTED				TITLE	
				FRACTIONAL $\pm \frac{1}{16}$, DECIMAL $\pm .005$, ANGLE $\pm \frac{1}{2}^\circ$				FORMED OUTER PLATE	
				REMOVE ALL BURRS					
				MATERIAL				SCALE	DRWG. NO.
SYM.	ZONE	CHANGE	DATE	BY	CHK.	RE-1-15324-C			RE-1-15521-C