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SPECIFICATIONS FOR ARMY PACKAGE POWER REACTOR (APPR-1) FUEL AND CONTROL ROD COMPONENTS

R. J. Beaver
R. C. Waugh
C. F. Leitten

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Errata

SPECIFICATIONS FOR ARMY PACKAGE POWER REACTOR
(APPR-1) FUEL AND CONTROL ROD COMPONENTS

Please make the following corrections in the values for Boron-10 content in the subject report.

Page 6, Item C: Change B-10 content from 0.483 to 0.447.

Page 7, Item C: Change B-10 content from 0.392 to 0.363.

Page 8, Item 5: Change B-10 content from 0.02685 to 0.02482.

**Change 18.8% B-10 to 17.39 wt % B-10.

Page 10, Item 5: Change B-10 content from 0.0245 to 0.02267

**Change 18.8% B-10 to 17.39 wt % B-10

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METALLURGY DIVISION

SPECIFICATIONS FOR ARMY PACKAGE POWER REACTOR (APPR-1)

FUEL AND CONTROL ROD COMPONENTS

R. J. Beaver
R. C. Waugh
C. F. Leitten

DATE ISSUED

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TABLE OF CONTENTS

Page

I. Summary 1

II. Introduction 1

III. Stationary Fuel Element. 6

IV. Control Rod Fuel Element. 6

V. Control Rod Absorber Section. 7

VI. Material and General Design Specifications. 7

A. Composite fuel plates for stationary fuel element. 7
B. Composite fuel plates for control rod fuel element. 9
C. Composite plates for control rod absorber section. 11
D. Side plates and combs. 12
E. End adapters. 12
F. Brazing alloy. 12

VII. Procedures for Manufacturing Fuel Elements. 12

A. Fuel core manufacturing. 12
B. Assembling of component parts into stationary fuel units. . . 18
C. Assembling of component parts into control rod fuel units. . 20
D. Attachment of handles to side plates of the control rod fuel elements. 20
E. Brazing fuel elements. 20
F. Machining and attachment of end adapters to fuel unit. 22
G. Final inspection of fuel elements. 24
H. Identification system. 26
I. Cleaning. 27

VIII. Manufacturing Procedures for Absorber Sections. 27

A. Core manufacturing. 27
B. Plate manufacturing. 29
C. Manufacturing of the absorber section. 33
D. Identification system. 35

IX. Listing of Drawings Required in Manufacturing Fuel Assemblies and Control Rods. 35

X. Acknowledgment 37

SPECIFICATIONS FOR ARMY PACKAGE POWER REACTOR (APPR-1) FUEL AND CONTROL ROD COMPONENTS

by

R. J. Beaver, R. C. Waugh and C. F. Leitten

I. SUMMARY

Final specifications are presented on the stainless steel fuel and control rod components developed for service in the 10 megawatt Army Package Power Reactor, a heterogeneous, pressurized-water unit designed for producting power in remote locations. The specifications cover design and material requirements as well as the fabrication procedures developed and adopted for manufacturing the extended-life fuel element and the enriched boron-10 absorber section of the control rod. Included in the procedural specifications are methods for preparing uranium dioxide-boron carbide-stainless steel ceramet cores; techniques for roll-bonding this material into composite stainless steel plates; procedures for brazing these plates into flat-plate fuel units; and the finishing operations required to prepare the assembly for loading into the reactor core. Procedures are also described for manufacturing the absorber sections of the control rod. The procedural specifications are specific for manufacturing these components at ORNL, and merely represent a detailed guide in the event other fuel element fabricators are requested to furnish additional fuel elements and absorber sections.

II. INTRODUCTION

In 1953, the Metallurgy Division at ORNL initiated a program to develop reliable fuel elements and control rod absorber sections for the heterogeneous pressurized water 10 megawatt Army Package Power Reactor. This reactor was designed to produce economic power in remote locations. The minimum core life of one year was proposed, which necessitated a high uranium investment, a burnable poison, and corrosion resistant protective cladding for the fuel and absorber sections. The materials were to be relatively economical and simple to fabricate. After a careful survey of possible materials for fuel elements, it was decided to utilize

thin composite flat plates consisting of a fuel section containing uranium dioxide and boron carbide, in a low carbon type 302B stainless steel matrix, and a protective cladding of type 304L stainless steel. Each plate was joined to side plates and separated to permit necessary cooling during reactor operation.

Because of the hafnium shortage, it was necessary to select another high neutron absorbing material for the absorber section of the APPR control rod. It was decided for this application to utilize enriched boron contained in an iron matrix of composite stainless steel clad plates. These plates were joined together to form a rectangular parallelpiped.

As a result of the development work, specifications were prepared for manufacturing APPR-1 fuel elements and absorber sections. The completed components are illustrated in Figures 1 and 2. The stationary fuel unit consists of 18 flat composite plates separated a nominal distance of 0.134-in. by brazing into grooved stainless steel side plates. As illustrated, end adapters are welded to both ends of the unit for positioning in the reactor. Each fuel plate consists of a 0.020-in. thick fuel core containing 28.62 g U-235, in the form of uranium dioxide; 0.0268 g B-10, in the form of natural boron carbide; and 99.80 g of low carbon type 302B stainless steel. The core is prepared by powder metallurgy processing and is clad by roll-bonding with type 304L stainless steel. The final clad-core-clad thicknesses are 0.005-0.020-0.005-in., respectively. The fuel element of the control rod is similar in design except that the fuel unit is limited to 16 plates; has 9 cobalt-bearing flux suppressor combs at one end; and a handle instead of end adapters. Each fuel bearing section in the composite plate of this unit contains 26.11 g U-235 in the form of uranium dioxide; 0.0245 g B-10 in the form of natural boron carbide; and 91.56 g of low carbon type 302B stainless steel.

The absorber section of the control rods consists of four 0.155-in. thick composite plates, clad with type 304L stainless steel. These plates are welded together to form the sides of a rectangular parallelpiped illustrated in Figure 3. Each plate contains a 0.090-in. thick core of elemental boron in an iron matrix, prepared by powder metallurgy processing. The boron is enriched in B-10 at the 93 per cent level. The core in each plate contains 14.7 g of B-10.

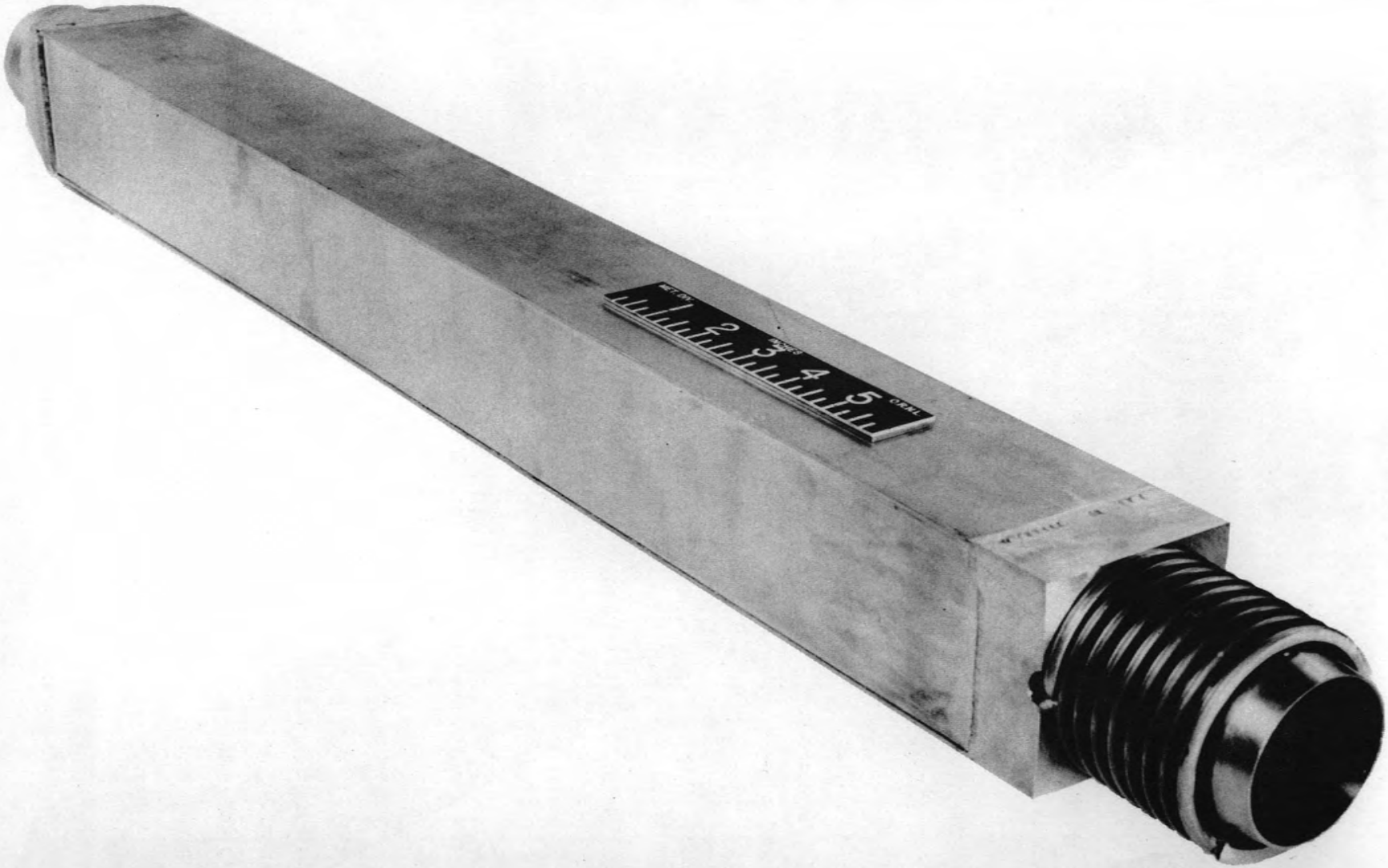

Fig. 1. APPR-1 Stationary Fuel Element.

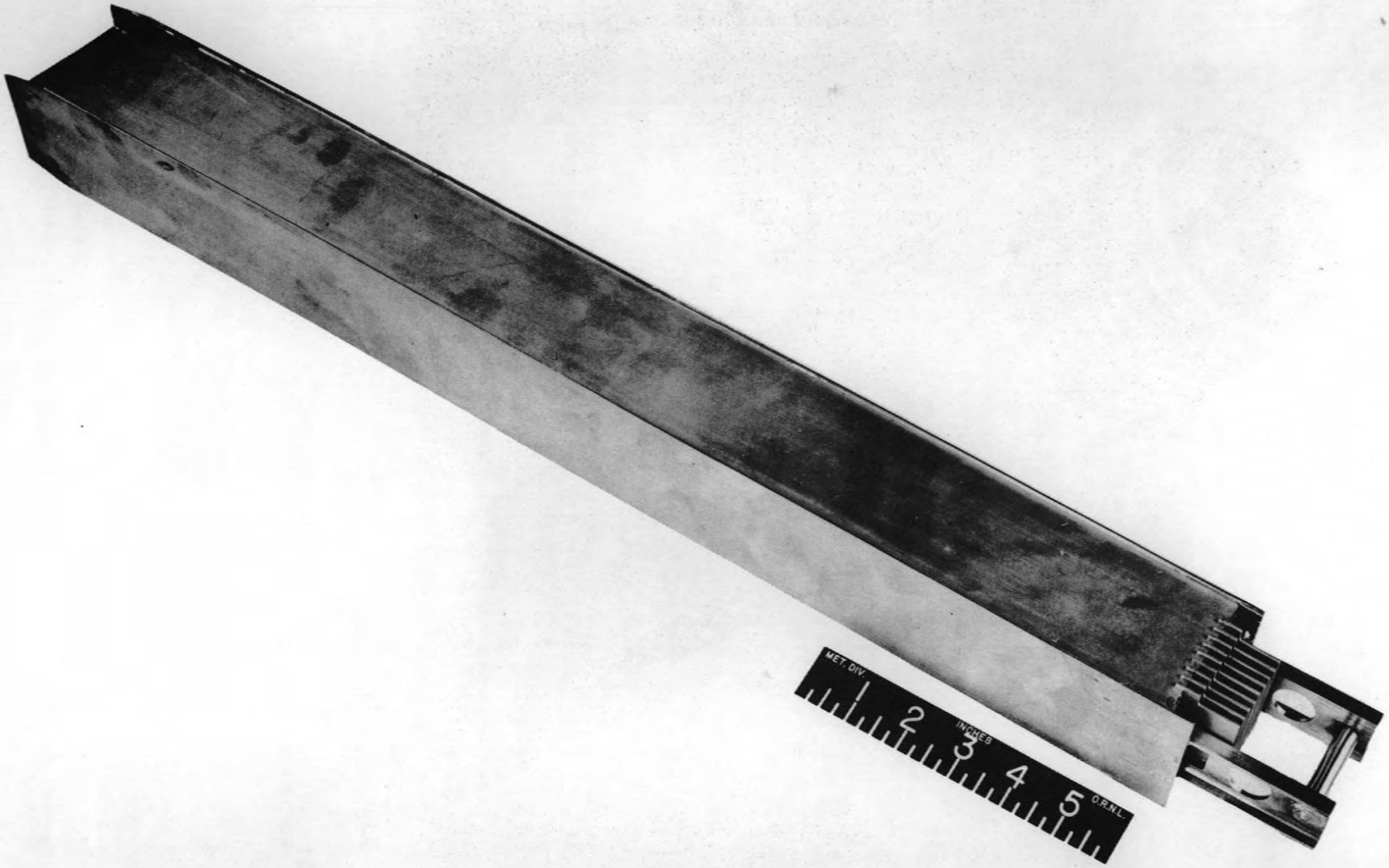

Fig. 2. APPR-1 Control Rod Fuel Element.

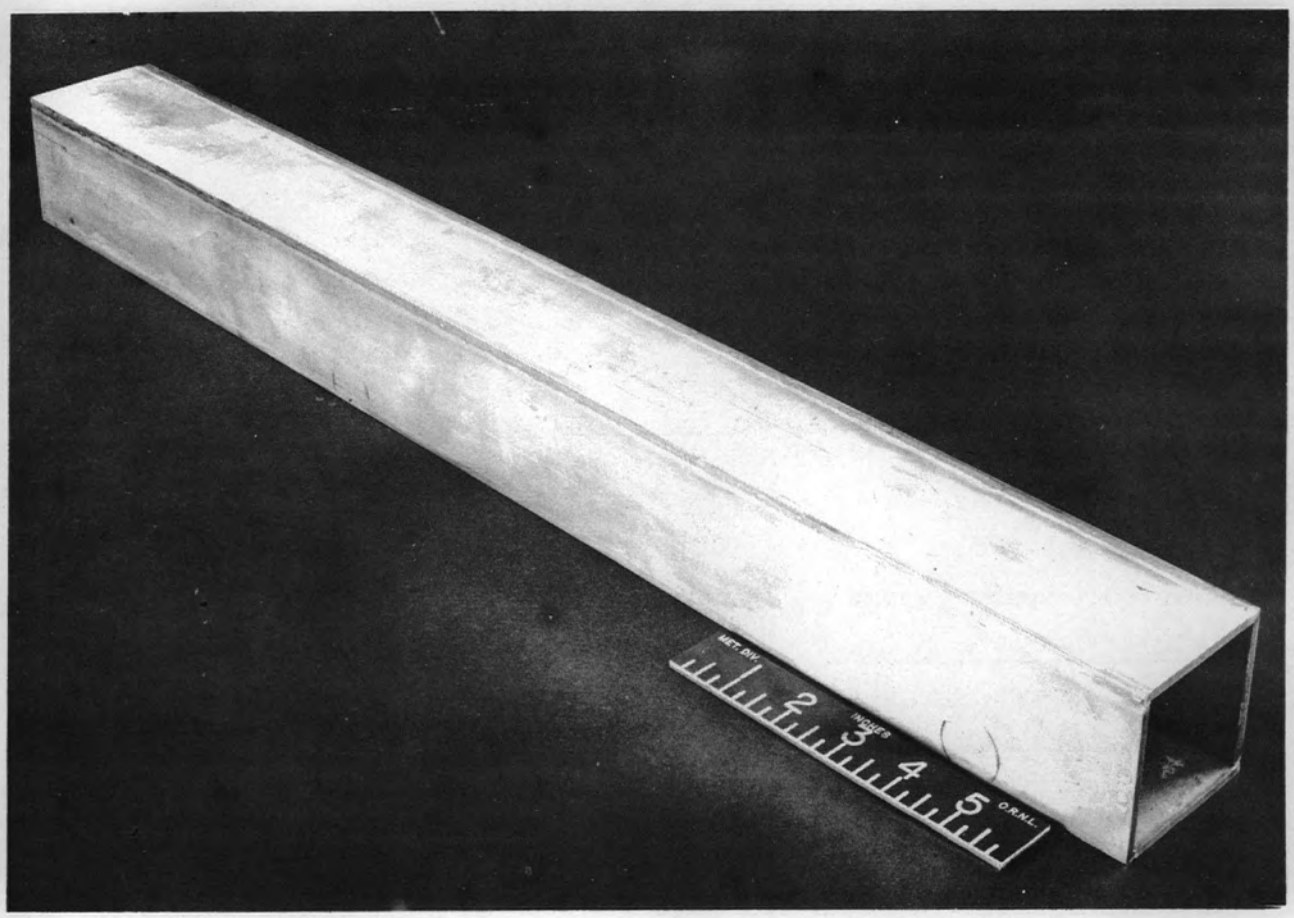

Fig. 3. APPR-1 Absorber Sections.

The specifications include the required quantities of the critical material and procedures for manufacturing the fuel and absorber sections for the reactor. The procedural specifications are based not only on past development work but also on experience in manufacturing 100 enriched APPR-1 fuel elements and 15 absorber sections.

III. Stationary Fuel Element.

A. Number of active plates per fuel element.

1. Short plates	16	
2. Long plates	2	

B. Fuel content

1. U-235, grams	515.16		
2. Tolerances			
a. Weighing	± 0.03%		
b. Enrichment assay	± 0.10		
* c. Ratio of $U_{T_{\text{@}\tau_r}}/UO_2$	± 0.25		
d. Handling	- 0.19		
Totals		+ 0.38%	- 0.57%
3. Enrichment	Highly enriched		
4. UO_2, approx. grams	631.66		

C. Boron-10 Content, Grams 0.~~483~~ .447

1. Tolerance			
a. Natural boron in boron carbide (75.9%)	± 1.00%		
b. Weighing	± 0.30%		
c. Possible losses during sintering	- 3.50		
d. Handling	- 0.20		
Totals		+ 1.30%	- 5.00%

IV. Control Rod Fuel Element.

A. Number of active plates per fuel element.

1. Short plates	14
2. Long plates	2

* $\text{Ratio} = \frac{\text{Free } U}{\text{Combined } (UO_2)}$

B. Fuel content.

1. U-235, grams	417.76		
2. Tolerances			
a. Weighing	± 0.03%		
b. Enrichment assay	± 0.10		
c. Ratio of U_T/UO_2	± 0.25		
d. Handling	- 0.19		
Totals		+ 0.38%	- 0.57%
3. Enrichment	Highly enriched		
4. UO_2, approx. grams	512.23		
C. Boron-10 content, grams	0.~~392~~ .363		
1. Tolerances			
a. Natural boron in boron carbide (75.9%)	± 1.00%		
b. Weighing	± 0.30%		
c. Possible losses during sintering	- 3.50		
d. Handling	- 0.20		
Totals		+ 1.30%	- 5.00%

V. Control Rod Absorber Sections.

A. Number of plates per section - 4

B. Total Boron-10 content, grams 56.4

Tolerances ± 1.0%

VI. Material and General Design Specifications.

A. Composite fuel plates for stationary fuel element.

1. Uranium Dioxide Powder -- Shall contain approximately 88% uranium in which the U-235 isotope has been upgraded to 93%. Powder of a selected size (44 to 88 microns) shall be prepared as follows:

a. UO_3 hydrate crystals shall be grown hydrothermally in an autoclave at 250°C for 10 hr from a UO_4 hydrate - 10% uranyl nitrate aqueous solution.

b. The UO_3 hydrate crystals shall be rinsed thoroughly to remove all traces of nitrate.

c. The rinsed UO_3 hydrate crystals shall be fired at 1750°C under a

hydrogen atmosphere during which the hydrated water is removed and the material is reduced to UO_2.

d. The material shall be screened and the 44 to 88 micron size range removed.

e. Only material free of agglomerates, platelets, rods, and clinging surface fines shall be acceptable.

2. Prealloyed Stainless Steel Powder -- AISI low carbon stainless steel type 302B such as supplied by Vandadium Alloys Steel Co., Latrobe, Pa. in a size less than 149 microns and irregular particle shape. A typical chemical analysis for the powder used in APPR-1 shall be as follows:

C	0.07 wt %	Cr	- 18.22 wt %
Mn	- 1.00	Ni	- 8.52
S	- 0.012	Si	- 2.39
P	- 0.010	Fe	- Balance

3. Boron Carbide Powder -- Supplied by Norton Chemical Company, screened to less than 44 micron size containing 75.9% natural boron.

Tolerances ± 1.00%

4. Frame and Clad Material -- Wrought stainless steel AISI type 304L

5. Material balance of fuel bearing core section.

Material	Weight, grams	Weight, Per Cent	Uncertainty, Per Cent
U-235	28.62		+ 0.38 - 0.57
UO_2*	35.09	25.98	
B_4C**	0.1880	0.14	
B-10	~~0.02685~~ 0.02482		± 1.30
SS	99.80	73.88	+ 0.01 -0.20
Totals	135.08	100.00	

* Based on 87.63% U in UO_2; 93.07% enrichment.

** Based on 75.9% Nat. B in B_4C and ~~18.8%~~ B-10 in Nat. B.
17.39 wt % B-10

6. Heat transfer surface, cm^2.
   a. Minimum 338.6
   b. Maximum 362.8
7. U-235 Distribution per plate, g/cm^2.
   a. Minimum 0.079
   b. Maximum 0.085
8. Homogeneity.
   a. Uranium ± 2%
   b. Natural boron ± 20%
   c. The above values shall be based on the analytical results of six evenly spaced samples along the active core length of a prototype depleted APPR fuel plate prepared from materials which were blended and fabricated in accordance with APPR specifications.
   d. As a qualitative evaluation of homogeneity every 25th plate is to be radiographed and filed as a permanent record.

B. Composite fuel plates for control rod fuel elements.

1. Uranium Dioxide Powder -- Shall contain approximately 88% uranium in which the U-235 isotope has been upgraded to 93%. Powder of a selected size (44 to 88 microns) shall be prepared as follows:
   a. UO_3 hydrate crystals shall be grown hydrothermally in an autoclave at 250°C for 10 hr from a UO_4 hydrate - 10% uranyl nitrate aqueous solution.
   b. The UO_3 hydrate crystals shall be rinsed thoroughly to remove all traces of nitrate.
   c. The rinsed UO_3 hydrate crystals shall be fired at 1750°C under a hydrogen atmosphere during which time the hydrated water is removed and the material is reduced to UO_2.
   d. The material shall be screened and the 44 to 88 micron size range removed.

e. Only material free of agglomerates, platelets, rods, and clinging surface fines shall be acceptable.

2. Prealloyed Stainless Steel Powder -- AISI low carbon stainless steel type 302B such as supplied by Vanadium Alloys Steel Co., Latrobe, Pa. in a size less than 149 microns and irregular particle shape. A typical chemical analysis for the powder used in APPR-1 shall be as follows:

C - 0.07 wt %	Cr - 18.22 wt %
Mn - 1.00	Ni - 8.52
S - 0.012	Si - 2.39
P - 0.010	Fe - Balance

3. Boron Carbide Powder -- Supplied by Norton Chemical Company, screened to less than 44 micron size containing 75.9% natural boron.

   Tolerances ± 1.00

4. Frame and Clad Material -- Wrought stainless steel AISI type 304L

5. Material balance of fuel bearing core section.

Material	Weight, gms	Weight, Per Cent	Uncertainty Per Cent
U-235	26.11		+ 0.38 - 0.57
UO_2*	32.01	25.87	
B_4C**	0.1717	0.14	
B-10	~~0.0245~~ 0.02267	73.99	+ 1.30 - 5.00
SS	91.56		+ 0.01 - 0.20
Totals	123.74	100.0	

* Based on 87.63% U_T in UO_2; and 93.07% enrichment.

** Based on 75.9% Nat. B. in B_4C, and ~~18.8%~~ 17.39 wt. % B-10 in Nat. B.

6. Heat transfer surface, cm^2.

   a. Minimum 316.3

   b. Maximum 331.0

7. U-235 distribution per plate, g/cm^2.

   a. Minimum 0.078

   b. Maximum 0.082

8. Homogeneity.
   a. Uranium ± 2%
   b. Natural Boron ± 20%
   c. The above values shall be based on the analytical results of six evenly spaced samples along the active core length of a prototype depleted APPR fuel plate prepared from materials which were blended and fabricated in accordance with APPR specifications.
   d. As a qualitative evaluation of homogeneity every 25th plate is to be radiographed and filed as a permanent record.

C. Composite plates for control rod absorber section.

1. B-10 powder -- Supplied by Hooker Electrochemical Co., Niagara Falls, N. Y.
2. Iron powder -- Such as supplied by Plastic Metals Division of the National Radiator Co., Johnstown, Pa.: screened to -100 mesh particle size. A typical chemical analysis for the iron powder used in APPR-1 is as follows:

C - 0.03 wt %	P - 0.005 wt %
O_2 - 0.26	Cr - 0.008
Mn - 0.002	Ni - 0.020
S - 0.015	Fe - Balance

3. Frame and Clad Material -- Wrought stainless steel AISI type 304L.
4. Material balance of core in absorber plate.

Material	Weight, gms	Weight, Per Cent	Uncertainty, Per Cent
Enriched boron*	15.90	3.23	± 1.0
Iron	476.99	96.77	

* Based on 95.56% total boron in material and 92.82% B-10 in the total boron. Specifications require 14.1 g of B-10 per plate.

5. Homogeneity of B-10.

The above value shall be based on the analytical results of five evenly spaced samples along the length of an actual APPR-1 absorber plate prepared from materials which were blended and fabricated in accordance with APPR specifications.

D. Side plates and combs.

1. Side plates

Wrought Stainless AISI type 304L -- Supplied in U. S. standard gage 18 (nominally 0.050-in. thick)

2. Combs.

Haynes 25 Combs, (0.15%C-20%Cr-10%Ni-15%W-1%Si-1.5%Mn-2%Fe-Balance Co). Thickness is nominally 0.050-in.

E. End adapters.

Precision cast AISI type 304 stainless steel to 125 rms finish.

F. Brazing alloy.

Coast Metals NP Powder Alloy -150 mesh, such as furnished by Coast Metals, Inc., Little Ferry, N. J.

The chemical analyses for the powder based on ORNL results were:

Ni - 49.46	± 0.90 wt %		Mo - 7.55	± 0.50 wt %	
Fe - 26.58	± 0.90		P - 3.98	± 0.70	
Si - 11.30	± 0.15		Mn - 0.72	± 0.10	
			Cr - 0.41	± 0.25	

VII. Procedures for Manufacturing Fuel Elements.

A. Fuel core manufacturing.

1. Calculation of material required in the fuel cores.

a. The U-235 and the total uranium in the uranium dioxide varies from batch to batch. The U-235/UO_2 ratio shall be accurately determined for each batch of oxide prior to calculating the weight of UO_2 required to obtain the weight of U-235 specified per plate.

b. The natural boron in the boron carbide varies depending on the grade. The boron bearing material shall be chemically analyzed and the percentage of natural boron determined for each batch of boron carbide received prior to calculating the weight of boron carbide required to obtain the weight of B-10 specified per plate.

2. Weighing and blending.

a. The stainless steel, uranium dioxide, and boron carbide for each core compact shall be individually weighed in a four ounce capacity jar which serves as the blending container. The weighing of the uranium dioxide shall be conducted inside an especially designed dry box.

b. The jars shall be loaded into an oblique blender and blended dry for 2 hr. At this time approximately 0.1 g of dodecyl alcohol shall be added to each core mixture by means of an atomizer. The material shall then be reblended for an additional hour.

3. Cold pressing.

Pressing operations shall be conducted inside a dry box. The contents of each bottle shall be carefully transferred to the die cavity with the aid of a camel hair brush. A 50% by volume carbon tetrachloride-stearic acid mixture shall be used as a die lubricant. The core shall be formed by hydraulically pressing at 33 tsi to a nominal size of 1.80 x 2.40 x 0.310-in., and 1.80 x 2.18 x 0.310-in. for the stationary and control rod cores, respectively.

4. Sintering.

A stainless steel sintering boat containing ten compacts shall be placed in a high temperature furnace and fired for 1-1/4 hr at 1177°C (2150°F) in a dry hydrogen atmosphere. The minimum dewpoint maintained shall be at least -60°F as measured by an Alnor Dewpointer.

5. Coining.

Each core shall be coined at 33 tsi with two load applications in the cold pressing die.

6. Quality control and inspection.

The materials weight loss which occurs during core manufacturing shall be determined by weighing each batch of ten cores. Loss in excess of that corresponding to 1 g of U-235 per 18 plate assembly shall be cause for rejection. All cores shall be visually inspected for flaws.

7. Storage.

Acceptable cores shall be stored in a desiccator for subsequent use in the preparation of composite fuel plates.

8. Billet assembly.

a. Material and dimensions.

(1) Material: AISI type 304L

(2) Dimensions:

(a) Frame for stationary fuel plate.

Outside sheared dimensions: 4-7/16 x 4-1/2 x 0.280 in.
Inside punched dimensions: 1.856 x 2.430 x 0.280 in.
Width of shoulders: 1-1/32-in.

(b) Cover plates for stationary fuel plate.

4-7/16 x 4-1/2 x 0.065 in. as sheared

(c) Frame for control rod fuel plate.

Outside sheared dimensions: 4-7/16 x 4 x 0.280 in.
Inside punched dimensions: 1.869 x 2.205 x 0.280 in.
Width of shoulders: 29/32-in.

(d) Cover plates for control rod fuel plate.

4-7/16 x 4 x 0.070 in. as sheared

b. The frame and cover pieces shall be degreased and brushed with a stainless steel wire wheel prior to billet assembly. The cover pieces shall be preplaced and attached by spot resistance welding prior to heliarc welding of the billet edges. The corners of the billet shall be left unwelded for a nominal length of 1/4 in.

9. Hot rolling.

The billets shall be preheated for a minimum of 20 min in an open muffle purged with hydrogen. Furnace temperature shall be 1150°C

(2102°F). The billets shall be rolled to plates, preferably on a heavy duty mill such as 20-in. dia. x 30-in. face hot breakdown mill. The billets shall be reheated for a minimum of 2 minutes between each pass. After the final pass the plates shall be reheated for 2 min. and air quenched. They shall be reduced from an initial billet thickness of 0.410 in. for the stationary fuel plate and 0.420 in. for the control rod fuel plate to 0.040 in., nominal which represents 90.3 and 90.5% hot reduction, respectively. The reductions per pass, based on mil settings during the hot rolling sequences, shall be 2 at 10%, 1 at 20%, 4 at 40%, 2 at 30%, and 1 at 20%. The plate shall be rotated 180° about its longitudinal and transverse axes after each mill pass.

10. Fluoroscoping of hot rolled plate.

The core of the hot rolled plate shall be located by fluoroscopy and the plate marked for shearing of the excess periphereal stainless steel.

11. Shearing of hot rolled plate.

The hot rolled plate shall be sheared on a Power Squaring Shear to 3-1/2-in. wide and 22-in. long. The hot rolled plate may be pickled in a 15% HNO_3-5% HF-aqueous solution to remove oxide scale.

12. Cold rolling.

The plates shall be cold reduced preferably on a 4-high mill similar to the type provided with a 5-in. dia. work roll and a 14-in. face. The plates shall be reduced to a finished thickness of .030 in. ± 0.001 in. The reduction per pass shall be less than 5%. The rolls shall be lubricated with SAE-90 weight oil. The lubricant shall be removed from the finished plate by degreasing.

13. Marking and shearing.

After cold rolling, the composite plates shall be fluoroscoped to locate the fuel core section. A template, designed to locate the dimensions shown in the fuel plate drawings, shall be used to center

the fuel core within the plate. Markings shall be made on the inactive portions of the fuel plate to locate the edges to be sheared. The plates shall be sheared on a power driven shear, equipped with stops to shear to a 2-15/16-in. width. The plate shall be sheared 1/16 in. over finished size along all ends. The mechanics of shearing shall be to shear along the one marked edge, sighting by eye, place this edge against the stop, and shear the opposite edge. The ends shall be sheared along the marks located during the previous fluoroscopic examination.

14. Machining fuel plates.

Twenty-five sheared fuel plates shall be stacked between 1/8-in. thick aluminum plates in a jig and straddle machined to the final dimensions specified. After straddle machining to proper width, the plate shall be machined to the final length specified.

15. Degreasing fuel plates.

Each fuel plate shall be separately degreased. The degreasing shall be thorough and random plates from each batch of degreased plates are to be tested with absorbent paper such as Kleenex to insure that the plates are clean.

16. Deburring fuel plates.

The plates shall be placed on a flat surface, and the burr removed by filing.

17. Inspection of machined plates.

Each machined fuel plate shall be separately fluoroscoped and the dimensions inspected with a template designed to locate maximum and minimum fuel core boundaries specified. Those plates in which an inactive edge width of less than 0.100 in. is indicated shall be radiographed and the inactive edge accurately measured. Those plates with inactive edge widths of less than 0.100 in. shall be referred to the authorities responsible for operation of the reactor for approval to be used in fuel elements. Those plates which do not lie within the length boundaries specified but are not more than 1/2 in. out of tolerance shall be radiographed and the dimensions accurately

determined. These plates shall be referred to proper authorities for utilization as special cases. Acceptable plates shall be stored in a safe while awaiting further handling.

18. Assembling of fuel plates for flatten-annealing.

The completely fabricated and machined plates shall be flattened-annealed. A mixture of 1 part by volume of Fisher Polishing, Grade No. 1, 5F Precisionite Levigated Alumina and 10 parts water shall be brushed on one side of each plate. The plates shall be allowed to dry in air for 15 min and then shall be stacked together with the coated side of each plate adjacent to the uncoated side of its neighbor. The maximum number of plates per stack shall be 25. A batch shall be placed between two 3/8-in. thick stainless steel platens, containing bolt holes 5 in. apart along each longitudinal side. The fuel plates shall be centered with relation to the bolt holes and firmly pressed together by bolt pressure. The batch shall be placed in a drying oven at 150°C and allowed to dry at least 16 hr.

19. Annealing of fuel plates.

The stacked batch of plates shall be placed in a controlled atmosphere furnace at a temperature not exceeding 300°C. The furnace shall be purged with helium of at least a -40°F dewpoint as measured with an Alnor Dewpoint Recorder. The flow conditions shall be sufficient to purge air from the furnace. The temperature of the furnace shall be increased at a rate not to exceed 200°C per hr until the temperature reaches 650°C. The furnace shall then be purged with purified hydrogen, with a minimum dewpoint of -80°F as measured with an Alnor Dewpointer. The flow conditions shall be sufficient to bright-anneal stainless steel. The furnace temperature shall then be increased, at a rate not to exceed 200°C per hr until a temperature of 1125°C has been attained. The batch shall be held at this temperature for 3 hr per in. of stacked plates, and furnace cooled to 300°C or less.

Helium shall be purged througn the furnace until all hydrogen has been exhausted from the furnace. The batch shall be removed from the furnace and permitted to cool in air, to room temperature.

20. Cleaning of fuel plates after annealing.

The plates shall not be cleaned in a halogen containing acid. After removing the plates from between the platens, the alumina shall be removed by scrubbing in hot water. Care shall be exerted to insure that the plates do not become damaged. The plates shall be spaced in a holder to permit separation and dried thoroughly, either in air or in a drying oven.

21. Storage of plates.

The plates shall be stored in a safe prior to assembling into fuel elements.

B. Assembling of component parts into stationary fuel units.

The parts shall be assembled in a 300 series stainless steel fixture which confines the parts during assembling and brazing. The fixture shall consist of a 1-in. thick base plate with skids attached to the bottom of the plate to allow ease of insertion and removal of the fixture in the furnace. "U" shaped supports, 7/8-in. thick and spaced 5-1/2 in. apart, are rigidly fastened to the base plate. A comb holder is attached to one end during assembling, but removed prior to brazing. After assembling, a baffle such as a 3-plate shield, consisting of .030-in. thick plates spaced 1/8-in. apart, shall be placed on top of the supports to minimize temperature gradients.

The procedure for assembling the fuel unit in the fixture is listed below:

1. Since flexibility is desired, the inside dimensions of the jig are designed oversize and shim plates are therefore required. Prior to assembling, the inside dimensions of the fixture shall be measured with a micrometer. The thickness of the shim plate shall be determined by substracting from the inside dimensions of the fixture, the width dimensions of the fuel plate; .010 in. of clearance for braze metal in the assembly joints; and .005 in. clearance in the fixture. These

measurements shall be made prior to assembling each unit to insure that no appreciable dimensional changes in the jig occur after brazing cycles.

2. Two shim plates shall be positioned against each row of supports.
3. Two side plates shall be positioned against the shim plates with the grooved sides facing each other.
4. A comb shall be placed in the comb holder, which shall be attached to the rear of the fixture.
5. The bottom fuel plates shall be inserted in the bottom grooves of the side plates and through the teeth of the rear comb. The fixture shall be rotated clockwise 45° from the horizontal and the dry braze metal powder applied through a .035-in. dia. hole drilled into a stainless steel cone-shaped applicator and spread along the entire length of the side-plate fuel-plate joint.
6. The dry braze powder shall be cemented in position by applying Colmonoy Nicrobraze Cement through 19 gage hypodermic needle attached to a 5cc syringe, and allowed to dry for at least 30 seconds.
7. A 1/4-in. wide stripe of Colmonoy Green Stopoff shall be applied adjacent to the cemented braze powder along the entire length of the plate.
8. The fixture shall be rotated counter-clockwise back to the horizontal and through the opposite 45°. Operations described in item 6 shall be repeated for the opposite side plate-fuel plate joint.
9. The balance of the short plates shall be individually assembled in the manner described in items 5, 6, 7, and 8. Assembly shall proceed from bottom to top.
10. Prior to inserting the top plate, the front comb shall be attached to the unit. Care shall be exercised so that all 16 short plates are fully inserted to the root of the slot. The dry braze powder shall be applied at the 16 short plate-comb joints, and the bottom plate-comb joint. The powder shall be cemented in place with Nicrobraze Cement.

11. After assembling the top plate and applying the braze powder and cement to the top plate-side plate joints, the comb holder shall be removed.
12. The fixture shall be rotated 90° horizontally and braze powder applied at the top plate-rear comb and top plate-front comb joints and cemented into place with Nicrobraze Cement.
13. A 1/2-in. wide stripe of Colmonoy Green Stopoff shall be applied across the width of the grooved surface of each side plate, 1 in. inside the front and rear of the fuel unit.

C. Assembling of component parts into control rod fuel units.

These units shall be assembled in the same manner as described in "B", with the following exceptions:

1. Nine Haynes 25 combs are placed at the rear of the fuel element. These combs are nominally 50 mils thick. The distance between the handles and the first comb is nominally 0.062-in. The distance between the other combs are nominally 0.133-in.
2. After assembling each plate, Coast Metals NP Braze Metal is applied on both sides of the top fuel plate - Haynes 25 comb joints.
3. After complete assembly the front comb is inserted through slots in the two inner long plates as the last operation and Coast Metals NP Braze Metal is applied on one side of all fuel plate-comb joints.

D. Attachment of handles to side plates of the control rod fuel assembly.

1. Prior to assembling, the handles shall be positioned on the grooved side of the control rod side plate and fastened by heliarc welding. The positioning shall be fixed so that the inside edges of the handles act as stops for the fuel plates during assembly.

E. Brazing fuel assemblies.

The procedures to be followed for brazing fuel assemblies are listed below:

1. Two calibrated chromel-alumel thermocouples shall be mechanically attached to front and rear of the fuel unit at the mid-plate location. Careful observations should be made during repeated cycles to

ascertain necessity for new thermocouples.

2. The baffle shall be placed on top of the brazing fixture prior to insertion of the fixture into the furnace.
3. The fixture, containing the fuel unit with attached thermocouples, shall be inserted into the furnace at a location in which the thermal gradient from rear to front of the fuel unit does not exceed 10°C.
4. The temperature of the furnace upon insertion of the fuel unit shall not exceed 300°C.
5. The furnace shall be maintained under a helium purge during insertion of the fuel unit.
6. After insertion, the furnace door shall be closed and the temperature of the furnace increased at the rate not to exceed 200°C per hour. The helium purge shall continue until the furnace temperature has exceeded 650°C. The dewpoint of the entering helium is to be recorded on the Alnor Dewpointer and shall be at least -40°F.
7. After the furnace temperature reaches 650°C, hydrogen shall be purged through the furnace. The entering hydrogen should have a dewpoint of at least -80°F as recorded by the Alnor Dewpointer. The flow conditions of the hydrogen shall be sufficient to permit bright-annealing of stainless steel.
8. Temperature shall be recorded every 15 minutes from the thermocouples on the fuel unit, as the unit is slowly heated. The thermal gradient along the length of the fuel unit at 700°C shall not exceed 25°C. Dewpoint measurements are to be recorded every 30 minutes.
9. When the fuel unit reaches a temperature of 1000°C, the thermal gradient shall not exceed 10°C. The dewpoint of the exit hydrogen at this temperature shall be at least -50°F as recorded by the Alnor Dewpointer.
10. When the fuel unit reaches a temperature of 1100°C, the temperature shall be recorded every 60 seconds. The braze metal flows at 1130°C. When the fuel unit reaches this temperature care shall be exerted to insure that the time above 1130°C does not exceed 8 minutes.

11. After brazing, the fuel unit and fixture shall be furnace cooled to at least 300°C, prior to removal from the furnace.
12. If during the heating cycle, one of the thermocouples loses calibration, the unit shall be permitted to heat to brazing temperature, and temperature measurements recorded with the remaining thermocouple.
13. Prior to removal of the fixture from the furnace, the furnace is to be purged with helium at a sufficient rate and length of time to insure that the furnace atmosphere will not contain a combustible mixture.

F. Machining and attachment of end adapters to fuel unit.

The following procedures may be used to machine stationary fuel elements and weld end adapters to dimensions shown in the assembly drawing.

1. Premachining of the end boxes.

   The end boxes are purchased in the as-cast condition and are premachined as listed below:

   a. A special split mandrel mounted vertical on a milling machine shall be used to support the bored boxes while the extreme outside flat surfaces are straddle milled to 2.860-in. square.
   b. The above mill fixture shall be used to position the end boxes for machining the male end connection to the brazed fuel section. These shall be matched to the individual unit in order to insure a .002 to .003-in. clearance in the fuel unit.
   c. The inside of the boxes shall be given a hand polish to insure a 125 micro inch surface finish.

2. Premachining of the fuel unit.

   a. The as-brazed fuel unit shall be mounted in parallel vises on a mill table to allow access to both ends. Both ends shall be squared without removing the unit. The cut shall be made with the side of a long end mill.
   b. The excess braze metal shall be removed from the inside of the ends by hand, thus removing interference of the braze metal to the insertion of the end box.

3. Assembly of parts.

   a. The end boxes shall be inserted in the fuel unit with 1/32-in.

welding clearance left between the end of the fuel unit and the shoulder of the end box.

b. Alignment shall be checked with an indicator on the squared section of the end box and the center and edges of the side plates.

c. Combination quench bars and clamp pads shall be placed approximately 1/8 in. from the end of the fuel unit. A 1/16 x 1 x 3-in. stainless strip shall be used under a "C" clamp over the side plates and a 1/8 x 2 x 2-1/2-in. aluminum strip shall be placed under the "C" clamp holding the ends of the fuel plates.

d. Alignment of the end box with the fuel unit shall be rechecked after drawing the above clamps snug.

e. The assembled unit shall be placed in a welding jig which clamps both the end box and the fuel unit to further insure the maintaining of alignment of the end boxes during welding.

4. Welding.

All welding shall be done by the "heliarc" method. No filler material shall ordinarily be used. In case of excess gap, a low carbon type 308 stainless steel filler metal may be added. Attachment of end adapters shall be as follows:

a. A tack weld shall be made at the center of one of the side plates.

b. The opposite side plate shall be welded in its entirety.

c. The tacked side plate shall be welded over its full width.

d. The fuel plates shall be welded to the end adapter.

e. The opposite end of the fuel unit shall be welded as described above.

f. The welded assembly shall be measured for alignment as specified in stationary fuel element drawing.

5. Final Machining.

a. The end boxes shall be turned between centers in an engine lathe.

b. Small 4-jaw chucks shall be mounted on either end of the lathe to allow freedom in shifting for trueing of the center line.

c. The centering points "D" and "E", shown in ALCO Fuel Element Drawing, shall be established on the fuel unit.

d. The unit shall be placed in the lathe between the two 4-jaw chucks with the inlet end box at the tailstock and shifted to bring the imaginary center at points "D" and "E" in true center.

e. Beginning with the inlet box, the round sections of the end boxes shall be turned to 5 mils above finished dimensions.

f. The alignment shall be rechecked prior to taking the finish cut to produce the 125 micro inch finish desired.

g. The fuel assembly shall be removed from the lathe.

h. The fuel assembly shall be placed in parallel vises on the milling machine. The ends of the end boxes shall be milled to proper length and the length of the fuel element finished to specifications.

i. The retaining hole for spring shall be located, milled and countersunk.

j. The unit shall be removed from the milling machine and a hole drilled for positioning the pin. A drill jig shall be used to insure duplication of this pin from unit to unit.

k. Excess weldment, burrs, etc., shall be removed.

l. The alignment pin and spring shall be installed after final inspection of the fuel assembly.

G. Final inspection of fuel elements.

1. Stationary fuel element.

a. Subsequent to brazing and prior to attachment of end adapters, the fuel unit shall be inspected as follows:

(1) Plate spacings.

Each plate spacing shall be measured with an elliptical probe at four locations along the length: 2-1/2, 10, 17, and 24-1/2 inches. This inspection shall result in 64 measurements. The average deviation from the nominal 0.133-in. spacing between plates shall not exceed ± 10 per cent. Measurements exceeding these tolerances shall be referred to responsible authorities.

(2) Distance from top and bottom plates to the edges of the side plates.

The distance from the top surface of the top plate and the bottom surface of the bottom plate to the edges of the side

plate shall be measured with a depth micrometer. This inspection is to be repeated after the end adapters have been attached and final machining and cleaning operations have been completed. The nominal dimension shall be 0.033-in. with a deviation of ± .013 in.

(3) Assembly width.

The width of the fuel unit shall be measured at six locations along the length of the unit; namely, 1, 6, 11, 16, 22 and 26 inches, as well as two locations across the height of the unit. The inspection shall result in 12 measurements. The nominal measurement shall be 2.833 in. with a deviation of ± 0.011-in.

(4) Cross-sectional perpendicularity and length camber.

The fuel unit shall pass through a box 34-in. in length, with inner cross-sectional dimensions of 2.896 x 2.896 in.

b. The 2.250-in. diameter of the outlet end adapter and the 2.495-in. diameter of the inlet end adapter shall be inspected to facilitate subsequent concentricity inspection.

c. Rings shall be placed around the end adapters and the assembly placed in matched "V" blocks. Concentricity measurements shall be made with an indicator at points "D" and "E", shown in the fuel element assembly drawing, by rotating the assembly through 180°.

d. The element, with the attached end rings, shall be placed on "V" blocks which rest on a surface plate and the perpendicularity of surface "Z" to axis "Y" shown in the fuel element drawing, shall be measured with a square.

e. The nominal 29-1/4-in. length between shoulders of the end adapters, specified in the fuel element drawing, shall be measured with a 36-in. vernier caliper.

f. The nominal 33-5/8-in. total length of the assembly, as specified in the fuel element drawing, shall be measured with a 36-in. vernier caliper.

g. The fuel assembly shall pass through a box 34-in. in length, with inner cross-sectional dimensions of 2.896 x 2.896 in., without interference.

2. Control rod fuel unit.

a. Subsequent to brazing, the fuel unit shall be inspected as follows:

(1) Plate spacings.

Each plate spacing shall be measured with an elliptical probe at four locations along the lenth: 2-1/2, 10, 17, and 24-1/2-in. This inspection shall result in 64 measurements. The average deviation from the nominal 0.133-in. spacing between plates shall not exceed ± 10 per cent. Measurements exceeding these tolerances shall be referred to responsible authorities.

(2) Distance from top and bottom plates to the edges of the side plates.

The distance from the top surface of the top plate and the bottom surface of the bottom plate to the edges of the side plate shall be measured with a depth micrometer. The nominal dimension shall be 0.072-in. with a deviation of ± 0.013-in.

(3) Assembly width.

The width of the fuel unit shall be measured at 5 locations along the length of the unit; namely, 1, 6, 11, 16, and 22 in., as well as two locations across the height of the unit. The nominal measurement shall be 2.612 in. with a deviation of ± 0.011 in.

(4) Cross-section perpendicularity and length camber.

The fuel unit shall pass through a box, 26-1/16-in. in length with inside cross-sectional dimensions of 2.650 x 2.650-in., without interference.

H. Identification system.

1. Since the uranium dioxide is received in batches in which the U/UO_2 ratio varies, each batch of cores manufactured shall be designated with individual "AP" numbers.

2. Each billet shall be marked with its identifying "AP" number.
3. After hot rolling, each plate shall be marked with its specific "AP" number, which it will retain until the mill scale is removed.
4. After the mill scale is removed from the plates and the plates sheared to size for cold rolling, they shall be numbered serially by stamping the number at one end only. The numbers for the control rod plates shall contain the prefix "C".
5. After fluoroscopic examination but prior to shearing, the cold rolled plates shall be numbered serially by scribing its identifying number with an electric vibrator, 1/8-in. inside the marks at each end of the plate which locate the sheared length. The number for the control rod plate shall be prefixed with the letter "C" and shall be scribed at the plate end which is opposite the end which butts the absorber section.
6. After the fuel elements have been brazed, numbers shall be scribed with an electric vibrator on each side plate. The numbers for the stationary fuel elements shall proceed serially from "S-1" to successively higher numbers. The numbers for the control rod fuel elements shall proceed serially from "C-1" to successively higher numbers.
7. After the end adapters have been attached and the fuel elements machined to final size, the number identified on the side plates shall be stamped in digits 1/2-in. high, on the top and bottom sides of the outlet end adapter, 1/4-in. from the fuel plate-end adapter joint.

I. Cleaning.

1. After inspecting the machined fuel element, the element shall be degreased. The fuel element shall be vibrated while clean dry air is blown through to remove possible machine shavings, dirt, etc. The element shall be again degreased.
2. After cleaning, the openings in the end adapters shall be sealed with masking tape to prevent any contamination of the inner parts of the element during storage, and shipment.

VIII. Manufacturing Procedures for Absorber Sections.

A. Core manufacturing.

1. Calculations.

Enriched B-10 and iron are specified as the powder materials for the

absorber core. The required weight of enriched boron shall be calculated after each batch of boron received is analyzed for concentration of total boron in the material, and concentration of B-10 in the boron. Each billet contains three stacked cores. Under this procedure, the materials required for each core shall be calculated on the basis of 4.7 g of B-10 per individual core.

2. Weighing and blending.

The iron and boron powders for each individual core shall be weighed and placed in a four ounce capacity jar, which serves as the blending container.

Weighing tolerances of the iron are ± 0.010 g. Weighing tolerances of the boron are ± 0.003, - 0.000 g. The materials shall be blended dry for 2 hr in an oblique blender.

3. Cold pressing.

The contents of each blended jar shall be placed in the cavity of a 2.08 x 2.27-in. die, leveled, and cold pressed under 33 tsi. After pressing a quantity of cores, they shall be divided into groups of three and each group weighed. This weighing provides a base for ascertaining the average handling loss of each core prior to sintering.

4. Sintering.

Three groups of cores (9 cores) shall be placed on a stainless steel boat and sintered under hydrogen for 1 hr at 1121°C (2050°F). The minimum dewpoint for the hydrogen shall be -60°F as measured with an Alnor Dewpointer. Upon completion of the sintering operation, each group of cores shall be weighed and the average sintering loss per core recorded.

5. Coining.

The cores shall be coined under 33 tsi with the core centered in the die cavity.

6. Quality control and inspection.

The materials weight loss which occurs as a result of handling during core manufacturing is recorded. If the loss per batch of 3 cores exceeds 2.0 g, the batch shall be rejected. All cores shall be examined for flaws and dimensions measured.

7. Storage of cores.

Cores not being processed into billets shall be stored in a desiccator.

B. Plate manufacturing.

1. Frame material and dimensions.

a. Material -- AISI type 304L (.03 max C) stainless steel.

b. Dimensions:

(1) Outside length -- 4.297 ± 1/32 in.

(2) Outside width -- 3.875 ± 1/32 in.

(3) Inside length -- 2.297 ± 0.005 in.

(4) Inside width -- 2.108 ± 0.005 - 0.000 in.

(5) Thickness -- 1.000 ± 0.002 in.

(6) Finish -- 125 rms

(7) An entrance hole, 0.225-in. in diameter, shall be drilled in the center of the 3.875 dimension listed in (2) above, 3/8 in. through the edge. A corresponding 0.225-in. diameter hole shall be drilled perpendicular to and meeting the first hole to form a "T" and permit evacuation of the inner parts of the billet.

(8) Tolerances listed shall be held to prevent out-of-squareness of the inner and outer frame dimensions.

2. Cover plate material and dimensions.

a. Material -- AISI type 304L stainless steel.

b. Dimensions:

(1) Length --- 4-11/16 ± 1/32-in.

(2) Width --- 4-1/4 ± 1/32-in.

(3) Thickness --0.320 ± 0.005-in.

3. Evacuation stem material and dimensions.

a. Material -- AISI type 316 stainless steel tubing.

b. Dimensions -- 0.225-in. OD x 0.175-in. ID x 10.0-in. long.

4. Billet preparation.

a. All parts shall be thoroughly degreased and wire brushed prior to assembling.

b. The evacuating stem shall be inserted 1/8-in. into the hole provided in the frame and welded with a type 18-8 stainless steel filler rod to the frame. The tube shall be purged with helium during welding.

c. Three cores shall be stacked into the hole in the frame and the cover plates clamped to each side of the frame. The cover plates shall overhang the frame 3/16-in. on all sides to facilitate welding.

d. The cover plates shall be heliarc welded to the frame using two welding passes employing a type 18-8 stainless steel filler wire.

e. The billet shall be leak detected under water and 20 lb. helium pressure for defective welds.

f. The billet shall be evacuated to a final vacuum of less than 10 microns as indicated on a thermocouple vacuum gate. During this period, the billet shall be periodically heated to approximately 500°C to drive off any entrapped gases. The intermittent heating shall be continued until there is no further indication of loss in vacuum upon reheating.

5. Hot rolling.

The billets shall be preheated in hydrogen for 90 min at 1100°C in an open muffle. The billet shall be rolled on a heavy duty mill, such as a 20 x 30-in. mill, at a 10 per cent reduction per pass as recorded by mill settings. Reheat times while the billet is more than 0.500-in. thick shall be 5 min, with subsequent 3 minute reheating times until the billet is reduced to 0.154 to 0.156-in. actual thickness. A single rolling direction shall be maintained, although the plate shall be rotated 180° about its longitudinal axis after every pass. As the thickness of the plate approaches 0.170-in., the core length shall be measured. Between passes, during reduction from 0.170-in. to finished thickness, the core length shall be measured with a tape to insure that the plates are not rolled oversize in length. After the billet is rolled through the last mill pass, it shall be annealed for 5 min in the hydrogen-purged open

muffle. After this annealing period, the plates shall be air quenched to room temperature.

6. Shearing of plates after hot rolling.

   Because of the "end effects" at the core ends, the end of the plate which was the leading end during rolling shall be carefully identified. The plates shall be sheared on a power driven shear to 34-in. long, and within 1-1/2-in. of the trailing end of the core.

7. Pickling of plates.

   The hot rolled oxide shall be removed from the plates by cleaning in a 15 per cent HNO_3 5 per cent HF aqueous solution.

8. Flattening of plates.

   Six plates shall be painted with a thin film of levigated alumina-water mixture; stacked between two 3/8-in. thick stainless steel platens; tightly bolted together; and dried at 150°C for 2 hr. The pack shall be inserted in a protective atmosphere furnace, designed to bright-anneal stainless steel, held for 1 hr at 900°C, slowly furnace cooled to 300°C, removed from the furnace, and air cooled to room temperature.

9. Radiographing and marking of plates.

   Prior to radiographing, a stack of six plates shall be skim cut along one edge to obtain a true plate edge reference. Two radiographs of the plates shall be taken; the first to obtain overall dimensions, and the second to obtain a clear radiograph of the trailing end of the core. From these radiographs, measurements shall be taken and transposed to the plate to delineate the core on the surface of the plate in the following manner:

   a. Measurements obtained from the radiographs shall be transposed to the plate and the core area delineated. Markings shall be scribed on the plate to locate sheared and finished plate boundaries.

   b. The location of the trailing end of the core is critical since the engineering drawing specifies a minimum of a 1/4-in. of inactive stainless steel at this end. The end shall be located

from the radiograph, and a mark scribed 1/4-in. from the core end. From this scribed mark, a distance of 26-1/16-in. shall be measured to the opposite end of the plate, and a mark scribed. These marks shall represent the final machined plate length. Additional lines, 1/8-in. outside of the machining marks shall be scribed at the ends and along the edges. These lines shall represent the sheared length and width dimensions. An identifying number shall be scribed at the leading end of the plate which contains the nominal 5-in. length of inactive stainless steel.

10. Shearing of plates prior to machining.

In shearing to width dimensions, the plate shall be clamped to the shear table with three vices spaced at equal intervals along the plate length. The plates shall be sheared in a powder driven shear suitable for shearing 3/16-in. thick stainless steel. It shall not be required to clamp the plate ends prior to shearing.

11. Machining to final size.

Each plate shall first be machined to final width dimensions. One side of the plate shall be clamped on the mill table and securely locked into position. The opposite side shall be machined to the machining marks. The clamps shall be removed without disturbing the plate, and the opposite side of the plate clamped and securely locked into position. The remaining sheared side shall be machined to the machining marks in the manner as described.

The end of the plate at which the minimum 1/4-in. active stainless end is specified and individually machined to the scribed machining mark. In machining to final specified length, six plates shall be stacked and the opposite end machined.

12. Degreasing and deburring.

The plates shall be degreased and deburred by placing the plate on a flat plate and mechanically filing at a 45° angle along all edges.

13. Final inspection of plate.

All finished machined plates shall be radiographed to delineate the

inactive stainless steel in which the core is encased. Measurements shall be made from the radiographs to determine acceptance or rejection. Plates with less than 0.080-in. inactive stainless at any point along the edges shall be rejected. Plates with less than 3/16 in. at the end specifying a nominal 1/4-in. inactive stainless shall be rejected.

C. Manufacturing of the absorber section.

1. All plates shall be degreased prior to assembling.
2. A graphite block, 2.307-in. square and 26-1/16-in. long shall be used to position the plates to meet specified inner dimensions for the absorber section. A 1/2-in., 45° cut shall be machined from all corners of the block to prevent contact of graphite and stainless steel during subsequent welding.
3. Assembling and welding procedures.
   a. Plate No. 1 shall serve as the base plate and lie on a flat surface plate.
   b. The graphite block shall lay on plate No. 1. The right side of the block shall lie approximately 0.155-in. inside the base plate.
   c. Plate No. 2 shall be placed perpendicular to the surface plate, with the edge butting the surface plate and its inner surface butting the edge of plate No. 1.
   d. Plate No. 3 shall be placed perpendicular to Plate No. 1 with its edge butting the inside of plate No. 1.
   e. Plate No. 4 shall be placed on top of the graphite block, with its right edge butting the inner surface of plate No. 3 and its inner surface butting the edge of plate No. 2.
   f. The plates shall be assembled with all identifying plate numbers at the same end of the absorber section.
   g. The assembly shall be rigidly held together with 5-in. "C" clamps. After clamping, the end of the section with the 1/4-in. nominal inactive stainless shall be squared. The width and height of the

box shall be measured with a micrometer. If dimensions are less than 2.600-in., a shim shall be placed at the proper joints to increase the dimensions to 2.619 ± 0.010-in.

h. At this time, only the joints between plates No. 1 and 2 and No. 1 and 3 shall be heliarc welded. These joints shall be first tack welded at the corners. Three-inch long welds shall be initiated from the corners inward along the length, and staggered from opposite corners until a continuous weld has been produced along the entire joint. No filler rod shall be used.

i. After cooling to room temperature, the "C" clamps shall be removed from the assembly, and the top plate and graphite jig removed.

j. A second graphite jig shall replace the previous jig. The two wedge-shaped parts fit together to form a rectangular block with overall dimensions of 1.80 x 2.307 x 30-in. The split block wedge design is to permit ease of removal after welding. Since the width of the block is 1/2-in. narrower than the first block, it shall be centered in the partially welded absorber box with a 1/4-in. clearance between the sides of the graphite and the sides of the absorber plates.

k. The top plate shall be placed on top of the graphite block with its right edge butting the inner surface of plate No. 2 and its inner surface butting the edge of plate No. 3. It shall be secured with 5-in. "C" clamps.

l. The plate shall be heliarc welded to the two side plates in the manner described in item h. above.

m. While the absorber box is still warm, the clamps shall be removed and the split graphite block removed by tapping the wedge.

4. Final machining.

a. In accordance with the absorber assembly drawing, 3/8-in. diameter holes shall be drilled through the solid stainless steel sides of the absorber box, the holder pin driven through, and heliarc welded

to the sides of the box.

b. The edges of the box shall be rounded to a radius of approximately 1/32-in. by filing.

c. A chamfer shall be machined along the inside edges of the un-numbered end of the absorber section. This chamfer shall be approximately 45° and to a depth of 0.050-in.

d. The entire outer surface of the box shall be sanded with fine emery paper to remove any excess weld material.

e. The entire inner surface of the box shall be scratch brushed with a stainless steel brush to remove any surface contamination.

f. The final machined section shall be degreased.

5. Final inspection.

The absorber section shall fit through a test box 26-1/16-in. in length with inside cross-sectional dimensions of 2.650 x 2.650-in. without interference.

D. Identification system.

1. After the plates have been marked for shearing and final machining, a number shall be stamped on both surfaces of the plate inside the final machining mark at the end of the plate which has the nominal 5-in. length of inactive stainless steel. Each plate shall be numbered serially to successively higher numbers.

2. After the final inspection of the absorber section, a number 1/2-in. in height, shall be stamped on each plate 1 in. inside the end of the absorbing section which has the nominal 5-in. length of inactive stainless steel. Each section shall be numbered serially to successfully higher numbers.

IX. Drawings Required in Manufacturing Fuel Assemblies and Control Rods.

The engineering detailed drawings were prepared by ALCO Products, Inc., Schenectedy, N. Y., and may later be subjected to revision. Care shall be

exerted when manufacturing the fuel elements and control rods to ascertain that the drawings contain the latest revision and that these drawings are in the hands of the responsible parties. The items required, are shown in detail in the engineering drawings listed below:

1.	ALCO Dwg	D 9-13-2007	Rev.	12/28/55
2.	ALCO Dwg	D 9-13-2006	Rev.	12/28/55
3.	ALCO Dwg	D 9-13-2014	Rev.	4/17/56
4.	ALCO Dwg	D 9-13-2011	Rev.	12/28/55
5.	ALCO Dwg	R 9-13-1003	Rev.	5/2/56
6.	ALCO Dwg	D 9-13-1004	Rev.	3/30/56
7.	ALCO Dwg	C 9-13-2023	Rev.	3/30/56
8.	ALCO Dwg	C 9-13-2022	Rev.	3/30/56
9.	ALCO Dwg	C 9-13-2070		12/13/56
10.	ALCO Dwg	A 9-13-2078		12/13/56
11.	ALCO Dwg	A 9-13-2077		12/13/56
12.	ALCO Dwg	A 9-13-2024	Rev.	12/28/55
13.	ALCO Dwg	B 9-13-2008	Rev.	12/28/55
14.	ALCO Dwg	D 9-13-2017	Rev.	4/24/56
15.	ALCO Dwg	D 9-13-1002	Rev.	3/30/56
16.	ALCO Dwg	A 9-13-2019	Rev.	12/28/55

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