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SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

HFIR-FE-1

G. M. Adamson, Jr.
J. R. McWherter

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METALS AND CERAMICS DIVISION

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AUGUST 1964

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Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

I. SCOPE:

This specification covers requirements for two types of aluminum-base fuel elements which together will be used as the fuel assembly in the High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory (ORNL). Requirements are included for materials of construction, fabrication, assembly, inspection, and quality control to produce fuel elements in accordance with Company drawings.

II. DEFINITION OF TERMS:

Qualification: A demonstration of the Seller's ability to successfully conduct an operation or test to the satisfaction of the company.

Certification: A written statement of compliance with an individual requirement of this specification.

Lot: Material from a single ingot, or from other comparable starting material (for example, a single group of fuel cores), fabricated successively to a given size by identical procedures.

Batch: The amount of material (in the form used by the Seller) represented by a single sample, usually the amount of material in either the original vendor's final production operation or the shipping container.

Reactor: The High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory.

Fuel Assembly: The complete fuel loading for HFIR, consisting of both the inner and outer fuel elements.

Fuel Element: Either the inner-annular or outer-annular arrangement of fuel plates.

Fuel Plate: The individual uranium-bearing plates used to make up either the inner-annular or outer-annular fuel elements.

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II. DEFINITION OF TERMS (continued):

Fuel Core: The duplex rectangular parallelepiped section in the center of the fuel plate. It consists of a contoured fuel section and a complementary aluminum filler section.

Fuel Section: The shaped portion of the fuel core containing the U_3O_8.

Filler Section: The inert portion of the fuel core which is added to complement the shaped fuel section of the core to provide a rectangular parallelepiped core cross section; for the inner element it contains the burnable poison.

Billet: The assembly of fuel core, frame, and cover plates prepared for hot rolling.

Cover Plate: The aluminum plates making up the cladding or protective portion of the fuel plates.

Frame: The area of aluminum surrounding the fuel core which provides the edge sealing.

Core Hump: The thickest portion of the fuel section as located on the side of the plate containing the filler section.

Combs: The thin supports which fit between the ends of the fuel plates.

Core Outline: The closed figure resulting from drawing a line connecting the outermost particles of U_3O_8 as seen by an x-ray examination of the plane of a flat fuel plate.

Surface Density: The total quantity of uranium or boron contained in a volume described by the product of the plate thickness and a unit area parallel to the surface of the fuel plate.

Grooves: The circumferential channels cut into the side plates in which weld metal is deposited to join fuel plates to side plates.

Slot: The longitudinal channels cut into the surfaces of the side plates to receive the fuel plates.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

II. DEFINITION OF TERMS (continued):

Coolant Channel: The region between two adjacent fuel plates in which the cooling water flows.

Average Coolant Channel Thickness: The average normal distance between two adjacent fuel plates, measured in a plane at right angles to the longitudinal axis of the element.

III. GENERAL DESCRIPTION:

A. Reactor - The High Flux Isotope Reactor is being built by the Oak Ridge National Laboratory to provide research quantities of several of the transplutonium elements. The maximum unperturbed thermal neutron flux in the HFIR is to be approximately 5×10^{15} neutrons/cm^2·sec at a total power level of 100,000 kw and an average power density of approximately 2,000 kw/liter. These performance characteristics represent a significant extrapolation beyond the performance of present generation research reactors, thus requiring careful design and close control of the fabrication procedures. The reactor will consist of a cylindrical fuel region surrounded by an annular control region and a beryllium reflector, all of which are water cooled. These components are contained within a stainless steel-clad carbon steel pressure vessel.

B. Fuel Assembly - The entire fuel assembly of this reactor is made up of two fuel elements, each element consisting of an annular array of fuel plates (Fig. 1). The annuli are identified as the inner and outer fuel elements. The inner element consists of 171 identical fuel plates and the outer element consists of 369 identical plates differing slightly from those in the inner element.

The fuel plates are shaped into an involute configuration to provide maximum fuel volume with a graded fuel distribution, a uniform metal-to-water ratio, and a high heat transfer surface-to-core volume ratio, while maintaining a constant channel spacing.

The fuel elements are to be assembled by inserting formed fuel plates into slots in cylindrical side plates. The fuel plates are to be attached to the side plates by welds deposited in

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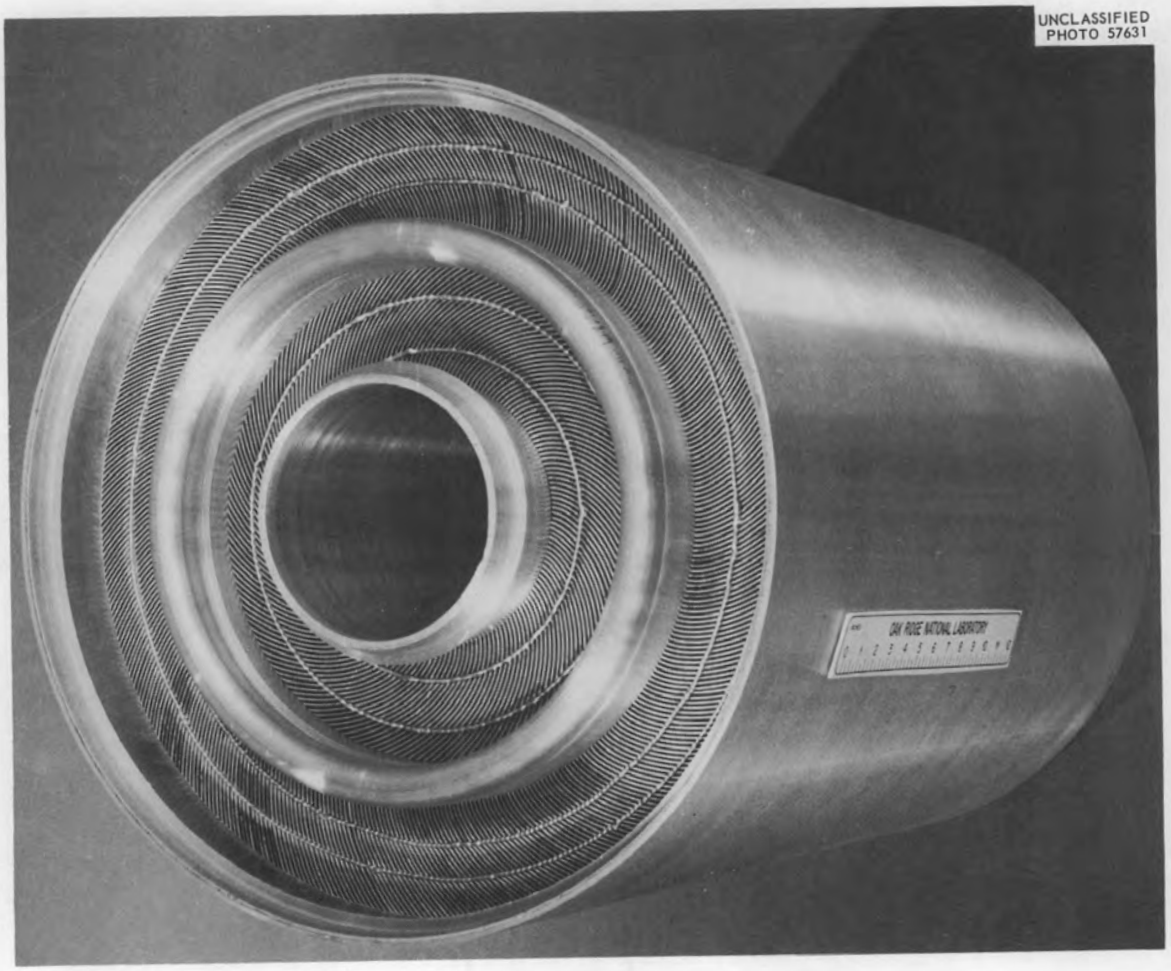

Fig. 1 Complete HFIR Fuel Element.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

III. GENERAL DESCRIPTION (continued):

B. circumferential grooves. To provide end stiffening for the fuel plates, combs are attached to the plates at both ends. End adapters are required on each end of the fuel assembly to provide location and support of the fuel assembly within the reactor.

C. Fuel Plates - Each fuel core, which constitutes a rectangular parallelepiped, consists of two mating sections: (1) a fuel section, varying in thickness across the width, and (2) an aluminum filler section which in the inner fuel element contains a burnable poison in the form of B_4C. The fuel and burnable poison surface densities are varied across the width of each plate to help control the power distribution. To help achieve satisfactory heat removal characteristics, it is necessary that the fuel and burnable poison distributions be closely controlled and that a sound bond exist at all interfaces within the plates. In addition to contributing to power distribution control, the B_4C located in the filler section of the inner fuel element fuel cores supplements the reactivity worth of the reactor control system.

IV. APPLICABLE DOCUMENTS

A. Fuel Element Drawings - The HFIR fuel elements are described in the following drawings which are a part of this specification.

D-42114 HFIR Inner Fuel Element - Fuel Plate Loading Details
D-42115 HFIR Inner Fuel Element - Top Combs
D-42116 HFIR Inner Fuel Element - Bottom Combs
D-42118 HFIR Inner Fuel Element - Assembly
D-42122 HFIR Outer Fuel Element - Fuel Plate Loading Details
D-42123 HFIR Outer Fuel Element - Top Combs
D-42124 HFIR Outer Fuel Element - Bottom Combs
D-42126 HFIR Outer Fuel Element - Assembly
D-42119 HFIR Fuel Elements - General Notes
D-42113 HFIR Inner Fuel Element - Fuel Plate True Involute Curvature Design Details
D-42121 HFIR Outer Fuel Element - Fuel Plate True Involute Curvature Design Details
D-42112 HFIR Inner Fuel Element - Inner Side Plate
D-42117 HFIR Inner Fuel Element - Outer Side Plate
D-42120 HFIR Outer Fuel Element - Inner Side Plate
D-42125 HFIR Outer Fuel Element - Outer Side Plate

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

IV. APPLICABLE DOCUMENTS: (continued):

B. Test Sample Drawings - Test samples which are required by this specification are described on the following drawings:

D-42142 Specimens and Holder for Welded Joint Strength Determinations
D-42143 Comb Welder Qualification Specimens
MC-215 Specimens for Evaluating Attachment of Fuel Plates to Side Plates

C. Reference Documents

ASME Boiler and Pressure Vessel Code, Section VIII, Appendix IV
ASME Boiler and Pressure Vessel Code, Section IX, Part B
ASTM-E 142-59T Tentative Methods for Controlling Quality of Radiographic Testing
ASTM-E 165-607 Tentative Methods for Liquid Penetrant Inspection
Special Nuclear Materials Article, SNM 6-62

V. MATERIALS:

A. Aluminum

1. General

a. All aluminum, with the exception of welding electrodes, welding rods, and aluminum powder, will be furnished by the Company.

b. This material will conform to one of the following specifications:

ASTM-B209-61, "Aluminum Alloy Sheet and Plate"
B-210-61, "Aluminum Alloy Drawn Seamless Tubes"
B-235-61, "Aluminum Alloy Extruded Tubes"

c. While this material meets the specified ASTM specifications, it is nevertheless special material in that the composition is controlled within narrower limits than is required by the ASTM specifications, such control being required for nuclear consideration.

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V. MATERIALS (continued):

A. 2. Aluminum Plate

a. The plate to be used for the fuel plate frames will be type 6061 aluminum and will be clad on both sides with type 1100 aluminum. The thickness of the type 1100 aluminum cladding on each side will not exceed 5.5% of the total thickness. Plates will be available as 36-in. x 96-in. plates 0.350 in. thick minimum.

b. The cover plates will be type 6061 aluminum, clad on one side with type 1100 aluminum, with the cladding being less than 5.5% of the total thickness. Plates will be available as 36-in. x 96-in. plates 0.142 in. thick minimum.

c. Material to fabricate the combs shall be prepared by the vendor from scrap cover plate material.

d. All plates will be furnished in the "O" condition to ASTM tolerances for size and surface. It shall be the responsibility of the Seller to achieve the actual thickness and temper condition required for fuel plate fabrication and to do any conditioning necessary to give closer tolerances, special surfaces, or any other feature required by the plate fabrication process. Fuel plate frames and cover plates shall be annealed by heating to 500°C $^{+5}_{-10}$°C for 120 min and cooling in air as a check for blisters. All blistered plates shall be rejected. 941/914

3. Tube

a. Aluminum as tubing for use as circular side plates and end fittings will be available in the following sizes:

Outside Diameter (in.)	Wall (in.)
5.562	0.500
6.375	1.000
11.250	0.938
12.250	0.875
12.250	1.500
17.875	1.000
17.875	1.312

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V. MATERIALS (continued):

A. 3. b. All tubing will be purchased in the T-6 condition.

4. Aluminum Powder

a. All aluminum powder will be Alcoa Type 101 Aluminum Powder (Alcoa Pigments, Paste, and Powder, Product Data Book, 6/20/60) or the equivalent, and will be furnished by the Seller.

b. All aluminum powder shall be annealed at 590°C ± 10°C for 4 hr at 7×10^{-4} torr.

c. A 100-g sample of as-received powder from each batch shall be furnished the Company by the Seller before the batch is used in a production element.

5. Welding Rods and Bare Electrodes

a. All welding rods and welding electrodes shall be of type 4043 aluminum and shall be furnished by the Seller.

b. All welding electrodes shall conform to Mil-E-16053K, "Electrodes, Welding Bare, Aluminum Alloys "

c. All electrodes shall be packed individually with a desiccant in hermetically sealed containers before shipping.

d. All welding rods shall conform to ASTM B 285-61T, "Aluminum and Aluminum-Alloy Welding Rods and Bare Electrodes."

e. A 60-in. representative sample of each lot of welding rod or welding electrode shall be submitted to the Company a minimum of two weeks before the lot is used in a production element.

B. Uranium Oxide

1. Enriched uranium in the form of UF_6, with the isotopic analysis, will be supplied without charge to the Seller by the Company.

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V. MATERIALS (continued):

B. 2. Conversion of the UF_6 to U_3O_8 shall be the responsibility of the Seller.

3. As furnished by the Company, the uranium will be enriched to a minimum of 93% of U^{235}. No degradation (within 0.2%) of the material will be permitted during conversion or element fabrication.

4. The U_3O_8 used as the fuel shall be a high-fired or dead-burned oxide having a density greater than 8.2 g/cc, as determined by a toulene pycnometer, and a surface area of less than 0.05 m^2/g, as determined by a krypton BET determination.

5. The total uranium concentration shall exceed 84.5 wt % with a maximum UO_2 content of 1.0%.

6. An analysis shall be required for each batch of U_3O_8.

a. The impurities in the U_3O_8 shall not exceed the limits specified in Table 1.

Table 1. Maximum Impurity Levels for U_3O_8 (ppm)

Al	10	Co	3	Mg	100
B	0.2	Cr	15	Mn	5
Ba	10	Cu	20	Na	5
Be	0.2	Fe	100	Ni	20
Ca	50	K	20	P	< 100
Cd	0.5	F	< 10	Si	50
		Li	1.0	V	2

7. As used in the core, the U_3O_8 shall be −170 +325 mesh and shall not contain more than 10% of −325 mesh particles, as determined in a standard screening test, ASTM B 214-56.

8. A sample with a minimum weight of 25 g shall be furnished the Company by the Seller from each lot of U_3O_8 used.

a. The sample must be packaged so as to avoid contamination from moisture.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

V. MATERIALS (continued):

B. 9. Handling of enriched uranium shall be in accordance with "Special Nuclear Materials Article," SNM 6-62.

10. Natural or depleted U_3O_8 used during development stages of this contract shall be obtained by the Seller. It should be obtained from the same manufacturer as the enriched material and should have been processed in a manner as nearly identical as possible.

C. Boron Carbide

1. Natural boron carbide (B_4C) equivalent to the High Purity Grade as supplied by Norton Chemical Company shall be used, and shall be furnished by the Seller.

2. A certified isotopic analysis for B^{10} shall be provided by the Seller for each batch of material.

3. A sample representative of the batch and with a minimum size of 50 g shall be furnished the Company by the Seller from each batch of B_4C used.

VI. FUEL PLATE REQUIREMENTS

A. Materials

1. All aluminum used in assembling the fuel plate billets shall be from lots furnished by or approved by the Company for such use.

2. All aluminum used in assembling the fuel plate billets shall be free from blisters as shown by visual examination while in the annealed condition.

3. All surfaces shall be clean and free from dirt, grease, lubricants, marking ink, pencil lead, and heavy oxides (section XIII).

4. All frames shall be of a one-piece construction.

VI. FUEL PLATE REQUIREMENTS (continued):

B. General Fuel Plate Requirements

1. Fuel plate surfaces containing any pits or scratches greater than 0.001 in. deep or dents larger than 0.25 in. in diameter shall be cause for rejection. With the approval of the Company, a mark located over the frame area may be used for purposes of core hump location (section VI-F).

2. The cover plates shall be bonded to both the core and frame surfaces.

   Note: Acceptable bonding is defined as no visible separation between the layers when viewed at low magnification and with grain growth evenly distributed across a minimum of 50% of the aluminum-to-aluminum portion of the interface length. A procedure qualified as specified in section XI-B coupled with quality control as specified in section XII-D shall be considered as meeting the requirements of this paragraph for the production of plates.

3. The operation preceding final machining for every flat fuel plate shall be the following anneal. Heat to 500°C $^{+5}_{-10}$ °C for 120 min and furnace cool at a rate of 27°C to 100°C or less. After removal from the furnace, the stack shall then be cooled to room temperature before removal of platens.

   Note: The purpose of this anneal is to yield closer control of the formed plates and to increase the reliability of the nonbond test (section VI-G-2).

4. The fuel plates shall be formed to within 0.015 in. of the true involute curvature. The duplication of fuel plates shall be limited to ±0.008 in. at 21 separate measuring points for the outer annulus and at 28 separate measuring points for the inner annulus. Seven measurements shall be taken at each of the radial locations shown below.

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VI. FUEL PLATE REQUIREMENTS (continued):

B. 4.

	Radial Location (in.)			
	Point No.			
	1	2	3	4
Inner fuel plate	3.18	3.77	4.58	5.14
Outer fuel plate	6.35	6.78	7.99	

The permissible tolerance on these radial locations is ±0.030 in.

5. A number shall be assigned to each fuel plate on completion of the hot-rolling operations. This number shall be maintained and used for plate identification in all operations thereafter.

6. After forming and prior to assembly, to remove heavy oxides formed during fabrication, every fuel plate shall be degreased and lightly etched in a cold HNO_3-HF (15 vol % – 1 to 2 vol %) solution followed by careful rinsing in potable water (XIII-A-2).

7. The thickness variation within any individual fuel plate shall not exceed ±0.0005 in.

C. Uranium Loading and Distribution

1. Each inner element plate shall contain 15.18 g ± 1.0% of U^{235} and each outer element plate shall contain 18.44 g ± 1.0% of U^{235}.

2. The uranium for each core shall be individually weighed and the weight recorded. The weights need be identifiable only by lot, not by individual plate.

3. Fuel plate cores shall be made as single units containing fuel and filler. All edges of the cores shall have a radius no greater than 0.010 in. Core thickness, after outgassing, shall not vary more than 0.004 in. in any core. All cores shall have an interference fit with their picture frames of 0.005 ± 0.003 in.

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VI. FUEL PLATE REQUIREMENTS (continued):

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C. 4. Fuel plate cores shall be vacuum annealed at 590°C ± 10°C for 3 hr with a maximum pressure of 1×10^{-4} torr during the major portion of the anneal.

5. After the picture frames and cover plates have been degreased and the cores have been vacuum annealed, they shall be handled with clean white gloves (section XIII-A-2).

6. The fuel plate billets shall be preheated for 45 min at 500°C $^{+5}_{-10}$°C prior to the first rolling pass. Between each pass, a reheat time of not less than 5 min shall be used except after the shearing pass where reheat time of not less than 10 min shall be used. The thickness of the hot-rolled plate shall be uniform within ± 0.001 in. (nominally 0.063 in.).

7. All fuel plates shall be rolled at room temperature to a final thickness of 0.050 in. ± 0.001 in. Thickness variations within any single plate shall not exceed ±0.0005 in. The average cold reduction shall be 20%.

8. Uranium shall not extend beyond the maximum core outlines as shown on drawings D-42114 and D-42122.

9. The uranium in the inner element plates shall be distributed in such a manner that the surface density in grams per square centimeter at any position X on the plate surface shall be equal to 0.0458 times the Y value corresponding to the position X as tabulated on drawing D-42114. For the outer-annulus plates, the uranium surface density shall be 0.0680 times the Y value as tabulated on drawing D-42122. Straight-line interpolation between tabulated points shall be used for additional values of Y.

10. The tolerance on the surface density in g/cm^2 of U^{235} within the maximum fuel core outline shall be +30% −100% of the specified value of that spot as measured for any 5/64-in.-diam spot (area of 0.0048 $in.^2$).

11. The tolerance on an average U^{235} surface density within the minimum core outline shall be ±10% of the specified value.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

VI. FUEL PLATE REQUIREMENTS (continued):

C. 11. In the area between the maximum and minimum core outlines, the variation of the average shall be within +10 −100% of the specified value. These averages shall be measured for a surface area 5/64 in. wide and varying in length from approximately 1/2 in. to approximately 1-1/2 in., depending upon the uranium concentration preceding any change in concentration and the magnitude of that change. They shall be obtained by continuously averaging the surface density within a 5/64-in. band along the plate length. An overlap of a minimum of 1/64 in. shall be maintained between scans.

Oak Ridge National Laboratory will furnish two instruments capable of inspecting the plates with the accuracy required to demonstrate whether the above requirements have been met. These instruments will be furnished free of charge, f.o.b, Vendor's plant. These instruments measure the intensity of an x-ray beam transmitted through the plate and,by comparing the attenuation with that obtained with known standards, determine the uranium concentration. The concentrations are averaged electronically using an RC time constant and a travel speed which will be specified by the Company. This constant will be such that an instantaneous change of 15% from nominal will reach an average value of +10% in approximately 1/2 in. of travel. The instruments will be capable of automatically completely scanning the plates and recording the data.

D. Boron Loading and Homogeneity

1. Each filler region for the inner element fuel plates shall contain B^{10} in the form of boron carbide. The amount of B^{10} to be added will be specified by the Company and may be changed during the life of the contract; it will, however, lie in the range of 0.01 to 0.025 g of B^{10} per plate. The initial value, and one to be used unless otherwise notified in writing, shall be 0.0124 g.

2. The amount of B^{10} per plate shall be maintained within ±10% of the specified value.

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VI. FUEL PLATE REQUIREMENTS (continued):

D. 2. Note: It is expected that the amount of boron carbide added shall be corrected to a constant B^{10} value to cover varying B^{10} enrichments and boron concentrations within the as-received boron carbide.

3. The boron carbide for each filler piece shall be weighed individually.

4. Boron carbide shall not extend beyond the maximum fuel core outline.

5. The B^{10} shall be distributed in such a manner that the surface density at any point on the surface X shall be 1.72×10^{-5} times the corresponding Z value from the table on drawing D-42114. Straight-line interpolation shall be used for intermediate values of Z.

6. The surface density of B^{10} within any 0.20 in.^{2} area within the minimum core area of the inner annulus shall be within ±35% of the theoretical density. In the region between the two core outlines, the tolerance shall be +35% −100% of theoretical.

a. Conformance with sections XI-B&F and XII-B shall be considered as satisfying the requirements of this section.

E. Fuel Plate Dimensions

1. The fuel plates shall be rolled to the dimensions shown on drawings D-42114 for the inner annulus and D-42122 for the outer annulus.

a. To permit variations in the width of the fuel plates necessary to compensate for variations in the assembly or welding techniques, only the width of the fuel core is specified. The plate width may be varied by varying the width of the aluminum edge cladding.

VI. FUEL PLATE REQUIREMENTS (continued):

E. 1. b. Drawings showing the selected sizes and the tolerance limits for the width of the flat plates must be furnished by the Seller to the Company for approval prior to start of production.

2. After final machining, every fuel plate shall be checked to assure conformance with the specified core and frame dimensions.

Note: A qualified fluoroscopic examination shall be considered as being acceptable.

3. All fuel plates shall have an average cladding thickness on each surface greater than 0.010 in. with a minimum cladding thickness of 0.007 in. (section XII-D).

F. Core Hump Location - The Seller shall establish a procedure by which the core hump location of every fuel plate may be determined and its location indicated.

1. The hump location shall be established both as to where it is located across the plate width and toward which plate face it is pointing.

2. The hump location markings shall be recognizable after the plates have been machined to final size and assembled between the side plates (section VII-A-2).

G. Unbonded Regions

1. Blisters

a. If at any stage of plate fabrication a blister greater than 1/16 in. in diameter is observed, the plate shall be rejected immediately.

b. In the last anneal preceding the cold reduction, each plate shall be held at 500°C $^{+5}_{-10}$ °C for a minimum of one hour. After cooling, both sides of every plate shall be visually examined for blisters. Any blister larger than 1/16 in. in any dimension and which will remain after machining to size shall be cause for rejection.

VI. FUEL PLATE REQUIREMENTS (continued):

G. 2. Nonbonds

a. After the completion of the flat plate fabrication and while the plate is in the annealed condition, the entire surface of each plate shall receive an ultrasonic examination for nonbond.

b. The ultrasonic test shall be conducted with sufficient sensitivity to detect any 1/16-in.-diam (0.00307 in.^{2} area) nonbond or blister located either within the fuel core, the cover plates, or at the core-cover, cover-frame, or insert-cover interfaces. The sensitivity and reproducibility of the technique shall be established with calibration plates containing fueled cores and reference discontinuities.

c. Any response larger than that which is received from a 1/16-in.-diam (0.00307 in.^{2}) reference discontinuity shall be cause for rejection of the plate.

Note: An acceptable technique for the fabrication of reference discontinuities consists of cutting 1/16-in.-diam (0.00307 in.^{2} area) flat-bottom holes in the calibration plate. The flat bottoms shall be parallel to the plate surface. The hole may be plugged to provide an acoustic mismatch approximating that of a nonbond. A sufficient number of such discontinuities shall be placed within the plate to assure adequate scanning at all interfaces and at all locations.

VII. FUEL ELEMENT REQUIREMENTS:

A. General Requirements

1. The elements shall be assembled with the plates curved in the directions shown on the drawings.

2. The markings showing hump orientation (section VI-F) shall be used to demonstrate that the fuel cores are oriented as called for in the drawings.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

VII. FUEL ELEMENT REQUIREMENTS (continued):

A. 3. All side plate tubes shall be in the T-6 condition.

4. Elements shall be clean and free from foreign matter (section XIII).

a. Once the curved plates have been etched and rinsed (section VI-B-4), all future handling of the plate or the assembled element shall be with clean white gloves.

b. After the fuel element has been assembled, all machining shall be done dry to prevent foreign materials from becoming trapped in the side plate slots.

c. In assembling the fuel plates into the side plates, alcohol may be used as a lubricant (other lubricants may be used with the approval of the company); however, prior to welding the assembled element, it must be dried four hours at a temperature above the boiling point of any lubricant.

d. Potable-grade water and the necessary penetrant testing liquids (section XIV-B) may be used; no other liquids shall be permitted on or in any fuel element.

e. During handling and storage, the elements shall be protected from dust, dirt, shop grease, and similar contamination.

B. Dimensions

1. To assure control of fuel element coolant-channel thickness, three Teflon spacers 0.045 to 0.048 in. thick by 3/4 in. wide and 24 in. long shall be installed in each coolant channel before welding. One strip shall be approximately 1/2 in. from each edge of the fuel plate and the third approximately at the center of the fuel plate.

2. Every coolant channel thickness shall be 0.050 ± 0.010 in. when measured at any point.

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VII. FUEL ELEMENT REQUIREMENTS (continued):

B. 3. The average coolant channel thickness for any individual cross section shall be 0.050 ± 0.006 in. Measured values at the five (5) points specified in VII-B-4 shall be averaged for any one cross section.

4. The coolant channel thickness shall be measured continuously along the length of each coolant channel (except for the 1/2 in. at either end of the fuel plates where the combs are installed) at the following radial locations:

	Radial Location (in.)				
	Point No.				
	1	2	3	4	5
Inner fuel element	3.10	3.56	4.05	4.40	4.80
Outer fuel element	6.20	6.64	7.22	7.61	7.90

The permissible tolerance on these radial locations is ±0.10 in. Radial separation distance between adjacent measurement locations shall be within ±0.10 in. of dimensions specified in the above table. These measurements should be made before final machining and before installation of the end adaptors.

It will be the responsibility of the Seller to demonstrate to the satisfaction of the Company that the coolant channels are not measurably altered during subsequent fabrication operations.

5. The tolerances on the width of the fuel plates and the slot depth of the side plate must be such that under the worst conditions the nearest approach of the fuel material shall be a minimum of 0.045 in. from either side plate, as measured radially from the fuel element center line.

6. As assembled, the fuel plates shall protrude a minimum of 0.015 in. into the weld grooves of the inner side plate and 0.035 in. minimum into the weld groove of the outer side plate.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

VII. FUEL ELEMENT REQUIREMENTS (continued):

B. 7. The Seller shall develop a technique which will show that after final machining, the side plate minimum thicknesses as specified on the drawings have been met.

Note: An acceptable technique will be to machine three additional shallow grooves into the tubular side plates when the welding grooves are cut. These grooves are to be on the same surface as the welding grooves and are to be located approximately at the midplane and 10 in. toward each end. The grooves should be cut after the tube has been rough machined. The grooves should be cut through the excess metal and extend a maximum of 0.015 in. into the final side-plate thickness; a minimum radius of 0.005 in. is required at the bottom corners. After final machining of the element, the wall shall be examined and the depth of the grooves measured and a minimum wall thickness calculated.

8. Dimensional inspections shall either be performed with the parts at 68°F ± 1°F, or shall be compensated for temperature correction.

C. Records - The measured value of the twelve dimensions identified by Roman numerals on drawings D-42118 and D-42126 shall be recorded and identified by number. The record of these dimensions shall be transmitted to the Company.

D. Marking - Every fuel element shall be identified by a code marking engraved on the surface with symbols 3/4 in. high. The marking shall be located on the outer side plate surfaces as shown on drawings D-42118 and D-42126.

1. Two markings approximately 180° apart shall be engraved on each element.

2. The depth of the markings shall not exceed 0.020 in.

3. The marking code shall be agreed upon by the Seller and the Company.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

VII. FUEL ELEMENT REQUIREMENTS (continued):

D. 4. An engraved index mark, 1/4 in. long and 0.020 in. deep, shall be made on the bottom end adapter opposite any one coolant channel on each fuel element. This engraved mark shall be used for purposes of channel identification and assembly and inspection records. An arrow, 3/8 in. long, shall be engraved perpendicular to the index mark to indicate the direction of channel numbering sequence.

VIII. WELDING REQUIREMENTS:

A. General Welding Requirements

1. Three types of welded joints are used in each fuel element: type A (fuel plate attachment welds), type B (end adapter attachment welds), and type C (comb-to-fuel-plate welds).

2. Weld types A and B shall be made by machine welding, using the gas-metal-arc process. Weld type C shall be made manually using the gas-tungsten-arc process.

3. All welds shall be made only by qualified welders or welding operators and with procedures qualified in accordance with section X.

4. Quality control during welding shall be as specified in section XII-E and all welds shall be inspected as specified in section IX.

5. The Seller shall submit for Company approval prior to the start of fabrication detailed welding procedures that conform to requirements of this specification.

B. Requirements for Fuel Plate Attachment Welds (Type A Welds)

1. Each fuel plate shall be welded to both the inner side plate and the outer side plate at the 24 axial locations as shown on drawings D-42118 and D-42126.

2. Each type A weld shall have a minimum pullout strength of 100 lb when tested in tension, with the force applied normal to the bottom surface of the fuel plate slot (section X-C-2).

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VIII. WELDING REQUIREMENTS (continued):

B. 3. The weld penetration shall not extend more than 0.010 in. into the plate width as measured from the side plate surface (top of the slots) (section X-C).

4. The face side of each weld shall be free of defects such as cracks, incomplete fusion, and incomplete penetration; in addition, they shall be free from irregular bead contour, oxidation, and terminal craters in excess of that present on the approved quality standard. The quality standard used shall be a selected representative part of a procedure qualification test weld identified as such and approved by the Company.

5. The root side of the welds shall be free of gross oxidation, sagging, or warpage (IX-B-1-a).

6. The weld grooves shall be filled sufficiently so that after final machining, surface depressions are not present on the inner surface of the inner side plate of the inner element nor on the outer surface of the outer side plate of the outer element.

7. The porosity or voids on any exposed surface or cross section shall not exceed the size shown on the ASME Boiler and Pressure Vessel Code, Section VIII, Appendix IV Porosity Charts for plate 1/4 in. or less and size "assorted." The amount of both large and small pores shall be restricted to half the amounts shown on this figure.

8. It will be permissible to machine, grind, or file the weld (using carbon steel tools), below the surface level of the rough-machined tube without making a weld repair, provided the as-finished side plate surface is not penetrated.

9. Any defects extending into the final thickness,other than those arising from the permissible minor porosity, shall be called to the attention of the Company representative who will make a decision as to whether a weld repair shall be made.

Subject: SPECIFICATION FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

VIII. WELDING REQUIREMENTS (continued):

C. Requirements for End-Adapter Attachment Welds (Type B Welds)

1. Each type B weld shall be free from defects such as cracks, oxidation from inadequate shielding, incomplete or discontinuous fusion, surface porosity, overlap, and irregular bead contours. The quality control standard weld selected for type A welds (section VIII-B-4) shall also be used for judging quality of the type B welds.

2. Porosity and slag inclusion, as shown by a radiograph (section XIV-A) shall not exceed the size or distribution shown for "medium" for plate 1/4 in. or less, with a single indication of size "large" as shown on the Porosity Charts, Appendix IV, ASME Boiler and Pressure Vessel Code, Section VIII.

3. The weld shall penetrate the full thickness of the side plate; no area of incomplete fusion shall be permitted.

4. Any defects, other than those arising from the permissible minor porosity or terminal craters or from defects which occur in the area of excess side plate material, shall be called to the attention of the Company representative who will decide if a weld repair is to be attempted.

5. The weld grooves shall be sufficiently filled so that after final machining, surface depressions are not present on the inner surface of the inner element nor on the outer surface of the outer element.

D. Requirements for Comb-to-Fuel Plate Welds (Type C Welds)

1. Each end of each fuel plate shall be welded to the combs.

2. All welds shall have smooth, rounded surfaces and be free from overlaps, incomplete fusion, excessive oxidation, and cracks or "crack like" indications.

3. Weld width at any location shall not be greater than 1.3 times the comb width.

4. Melting of comb teeth shall not extend to a depth greater than 1/8 in. below the end of the fuel plate.

IX. WELD INSPECTION:

A. Preweld Inspection

1. Before welding, all joints shall be visually inspected for alignment of parts, proper joint geometry, and cleanliness.

2. For each type A weld, the protrusion of fuel plates into the weld grooves shall be determined by making complete measurements in a minimum of three weld grooves for each side plate, these being one on each end and one in the center of each tube.

   a. All protrusions shall meet the requirements of section VII-B-5.

B. Postweld Inspection

1. Welds shall be visually inspected for compliance with their respective portions of sections VIII-B, VIII-C, or VIII-D.

   a. The inside surfaces of type A welds shall be inspected visually, with a light at the far end, for compliance with section VIII-B-5.

2. The face of each type A or type B weld shall be penetrant inspected using the technique in section XIV-B.

3. Each type B weld shall be inspected radiographically in accordance with the techniques in section XIV-A.

   a. Each weld shall meet the requirements of section VIII-C.

4. Each type C weld shall be visually inspected using a low-power (approximately 5X) reading glass or comparable optical lens.

   a. All welds must conform with section VIII-D.

5. A minimum of three measurements of weld width at the thickest portions of each welded comb shall be made; all shall comply with section VIII-D-3.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

X. QUALIFICATION OF WELDING PROCEDURES, WELDERS, AND WELDING OPERATORS AND EQUIPMENT

A. General Requirements

1. The Seller shall qualify welding procedures, welders, welding machine operators, and welding equipment by applying the rules for Procedure Qualification in ASME Boiler and Pressure Vessel Code, Section IX, Part B, and in accordance with additional requirements of this specification before any welding work is done on the prototype element or on the production elements.

2. Before repair welding on a production element, the repair welding procedures shall be qualified.

3. Welding procedures and certified qualification test results shall be submitted to the Company for approval prior to any production welding.

   a. Welding procedures must be clearly described in detail and shall include, but are not limited to, values and limits for such variables as voltage, amperage, gas type and flow rate, travel speed, wire feed rate, welding sequence, and type and model of welding machines.

   b. A statement shall be included as to what methods will be used to control the variables and what accuracy and reproducibility is obtained.

4. The various welding procedures shall be considered as being qualified when the first welder or welding operator using them is successfully qualified.

5. A welder or welding operator qualified for a given weld for one element shall be considered as being qualified for the same type of weld for the other element.

B. Preliminary Qualification of Welders and Welding Operators

1. Before qualifying for specific welds, all welders and welding operators shall be generally qualified by applying the rules for the Performance Qualification tests outlined in the ASME Boiler and Pressure Vessel Code, Section IX, Part B.

X. QUALIFICATION OF WELDING PROCEDURES, WELDERS, AND WELDING OPERATORS AND EQUIPMENT (continued):

B. 1. a. The qualifications shall be made using type 6061 aluminum base metal and type 4043 aluminum filler metal.

b. Welding operators who will be making type A or type B welds shall qualify by making machine welds in the 1G position using pipe or tube. Welders who will make type C welds will qualify manually with plate in the 1G position.

c. Samples prepared by the welding operators shall be required to pass the bend tests required of welders making similar welds.

C. Qualification of Type A Welding Operators

1. One test sample of the type shown on drawing MC-215, using type 6061-0 aluminum plates, shall be welded by each operator to demonstrate that he can successfully join plates protruding various distances into the weld groove.

a. Each weld of these qualification samples shall contain a section showing the start of the weld, the area where the finish of a weld overruns the start, and the point at which the arc was extinguished at the finish.

b. Each weld shall be inspected as specified in section IX and shall conform with the general specifications for type A welds (section VIII-B) as well as the special requirements discussed below.

c. Each weld shall be sectioned longitudinally at the center line, polished, and etched.

d. A minimum of 95% of the plates shall be welded to the side plate across the entire thickness of the fuel plate; the other 5% shall be joined over at least 75% of the thickness of the fuel plate.

e. The weld metal shall penetrate below the fuel plate side of the side plate surface a maximum of 0.010 in.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

X. QUALIFICATION OF WELDING PROCEDURES, WELDERS, AND WELDING OPERATORS AND EQUIPMENT (continued):

C. 1. f. The weld metal shall fill each groove a minimum distance of 0.20 in., as measured from the fuel plate side of the side plate.

2. Strength requirements of the fuel-plate-to-side-plate joints (section VIII-B-2) shall be demonstrated by the welding of samples shown on drawing D-42142, using type 6061-T6 aluminum side plates and type 6061-0 aluminum plates.

a. Joint breaking strength shall exceed 100 lb.

3. The final stage of the type A qualification shall consist of the welding of a full-size test element.

a. The element shall be assembled using plates prepared by the approved fabrication procedures, except the cores may be omitted. The fuel plate billets would be assembled in a normal manner except the frame material will not contain a hole for the fuel core (solid frame).

b. A minimum of four complete circumferential welds shall be made by each operator on both the inside and outside plates.

c. As welded, the element diameter and plate spacing shall meet the requirements of section VII.

d. All welds shall be inspected in accordance with section IX and shall meet the requirements of section VIII-B.

e. One inner weld and one outer weld shall be mounted, sectioned through the center of the welds, and suitably prepared for examination of the weld cross section.

f. These welds shall satisfy the requirements of sections VIII-B and X-C-1.

X. QUALIFICATION OF WELDING PROCEDURES, WELDERS, AND WELDING OPERATORS AND EQUIPMENT (continued):

D. Qualification of Type B Welding Operators

1. Each type B welding operator shall qualify by welding one full-size internal and one full-size external type B joint.

   a. Each weld shall be inspected as specified in section IX and shall meet the requirements of section VIII-C.

   b. Each weld shall be sectioned at two cross sections. Each cross section shall meet the requirements of section VIII-C.

E. Qualification of Type C Welders

1. Each welder qualifying to make type C welds shall weld a minimum of one subsize, flat plate assembly as shown on drawing D-42143 and one test element or cross section thereof, 360° around element.

   a. The comb in the test shall be placed to represent an equivalent diameter of any one of the combs in a fuel element.

   b. Both welds shall be visually examined in accordance with section IX and shall meet the requirements of section VIII-D.

   c. Each weld shall be sectioned longitudinally. The weld cross section shall meet the requirements of section VIII-D.

F. Requalification

1. If any specimen fails to meet any required specifications, a complete requalification for that type of weld shall be performed.

2. For such a requalification, twice the original number of specimens shall be welded and each specimen shall meet all the requirements and specifications.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

X. QUALIFICATION OF WELDING PROCEDURES, WELDERS, AND WELDING OPERATORS AND EQUIPMENT (continued):

F. 3. If additional attempts at qualification shall be required, the same number of samples shall be required as were required for the second attempt.

XI. PROCEDURE QUALIFICATION

A. Procedures and Drawings

1. Before the start of any production operations, the Seller shall prepare detailed shop drawings and fabrication and inspection procedures. These must include, but are not limited to, such items as core preparation, fuel plate fabrication, fuel element assembly, cleaning procedures, welding and inspection details, qualification and quality control tests, and storage and shipping procedures.

2. Both the shop drawings and procedures shall be submitted to the Company for written approval before being used for production operations. Any changes made after the original approval must be similarly approved before being used in the production operations.

3. A period of four weeks shall be allowed for the Company to approve the drawings and procedures.

4. Drawings and procedures returned "Unapproved" shall be revised by the Seller and be resubmitted for approval. Drawings and procedures returned "Approved Except as Noted" need not be resubmitted for further approval unless it is so requested.

B. Fuel Plate Qualification

1. Before starting his production operations, the Seller shall demonstrate that the fabrication and inspection techniques to be used for both the inner element and outer element fuel plates are capable of conforming to this specification. The fuel plate procedures shall be qualified by satisfactorily producing, in accordance with this specification, a minimum of twenty-five plates for each element. The plates for each

XI. PROCEDURE QUALIFICATION (continued)

B. 1. element shall be produced consecutively during a single operation. They shall be identical, including being machined to size, to the expected production plates. All inspection procedures shall be identical to those to be used during production.

a. A minimum of three-fourths of the flat plates fabricated during each of the qualification runs shall conform to the production portions of these specifications.

2. After final machining and inspection (section VI) and before forming, every qualification plate shall be remeasured and shall be radiographed to show the core outline and minimum edges.

3. Three curved plates from the qualification batch for each element, which have passed the normal inspection but which are otherwise selected at random, shall be destructively examined.

a. Each plate shall be completely sectioned transversely at three equidistant locations covering the length, and longitudinally at both ends in the center of the plate. The end cuts shall start approximately 1/2 in. beyond the core and shall extend into it for approximately 1-1/2 in.

b. Each section shall be examined for core dimensions, soundness of bond (section VI-B-2) and minimum cladding thickness (section VI-E-3).

4. The ability to control boron losses during processing shall be demonstrated by dissolving three complete inner-annulus plates and determining the total boron content of each.

a. The total boron content of each plate shall meet the requirements of section VI-D-1.

5. Adequacy of boron distribution shall be demonstrated by punching fifteen 1/2-in.-diam (0.20 in.^{2} area) samples from each of three randomly selected inner-annulus plates.

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XI. PROCEDURE QUALIFICATION (continued):

B. 5. a. For each plate, the samples shall be randomly located along three randomly selected rows of constant boron content, except that one row shall be on or near the core hump.

b. Each sample shall be analyzed for boron using procedures and standards approved by the Company.

c. The boron content of each sample shall comply with the specification of section VI-D.

6. If any qualification test plate is found which has passed the normal production inspection (section VI) but from which any sample has failed to pass the additional tests required for the qualification samples, a second batch of 25 plates shall be produced and tested.

a. Double the original number of plates shall be examined for the requirement which was not satisfied and all must be acceptable. For the other requirements, the original number of samples shall be examined.

7. Before the production of any reactor fuel plates is started, the results of the fuel plate qualification tests must be approved in writing by the Company.

C. Qualification of Fuel Homogeneity Inspection - Adequacy of the nondestructive inspection for fuel homogeneity shall be demonstrated by use of a special test plate to be furnished by the Company.

Note: This plate will contain defects of known magnitude.

1. The plate shall be examined three times during any qualification run, and the results shall check within the agreed-upon accuracy of the equipment.

D. Welding - The qualification tests required for welding are covered in section X.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XI. PROCEDURE QUALIFICATION (continued):

E. Qualification Elements

1. To qualify the assembly, welding, machining, and inspection techniques, a minimum of one inner and one outer full-size prototype element shall be assembled, inspected, and shipped to the Company.

2. These fuel elements shall be fabricated with procedures identical with (except as noted in section XI-E-3) and inspected by identical techniques to those to be used for the production fuel elements.

3. The fuel plates for the qualification elements shall not contain cores fabricated from enriched uranium. The cores shall contain depleted or natural uranium or may be omitted and the plate billets assembled using the normal frame material, but without the hole for the fuel core (solid frame).

4. Elements shall be machined to final dimensions using identical machining practices and equipment comparable to those used in production operations.

5. Elements shall be certified as complying with all the requirements of this specification.

F. Qualification Test Result Approval

1. Before any production operations involving welding, assembly, or machining are started, the results of the welding qualification test (section X) and the qualification element (section XI-E) must be approved, in writing, by the Company.

XII. QUALITY CONTROL

A. Uranium

1. A continuous and complete inventory of enriched U_3O_8 shall be maintained at all times for all steps in the production operation.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XII. QUALITY CONTROL (continued):

B. Boron

1. Continuing control of boron homogeneity shall be demonstrated by sampling one randomly selected inner-annulus fuel plate from the group for each inner element manufactured.

2. The plate shall be examined as discussed in section XI-B-5.

3. If this plate does not meet specifications, three additional plates shall be sampled, all samples of which shall meet the specifications; otherwise, the entire group of plates shall be rejected.

C. Scanning Device

1. That satisfactory operation of the homogeneity scanning device is being maintained shall be shown by re-inspecting the control plate (section XI-C) after every fifteen plates, through one scanner. Within the agreed-upon accuracy of the inspection device, the standard trace must be obtained.

   a. If a standard trace is not obtained, all production inspection on that scanner shall stop until the trouble is rectified. All plates inspected since the previous check shall be re-inspected.

2. The standard plate shall be the first plate inspected after any scanner has not been in use for periods of four hours or more.

D. Cladding Thickness and Bond Quality

1. A randomly selected plate from the group for each element shall be destructively examined as described in section XI-B-3 to show that minimum cladding thickness (section VI-E-3) and adequate bond quality (section VI-B-2) are being maintained.

   a. The same plate used for sampling in XII-B-1 may be used for these samples.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XII. QUALITY CONTROL (continued):

D. 2. If a blistered plate is found during the nonbond examination in processing the given lot of plates, it may be used for this test.

3. If any area in the samples from the selected plate does not meet the minimum cladding thickness or bond quality, three more randomly selected plates shall be examined. Unless all areas meet specification, the group shall be rejected.

E. Welding Quality Control

1. Immediately prior to welding the type A welds on each fuel element, one flat side plate assembly (drawing MC-215) shall be prepared. These samples shall be prepared using procedures and operators identical to those used on the element. They shall be examined in a manner identical to that in section X-C-1 and shall meet the same specifications. Results of the examination of these samples shall be used to evaluate the soundness of the fuel element type A welds.

2. If the specimen does not meet all requirements of the specifications, all production welding shall stop and two additional samples shall be assembled, welded, and examined.

a. Before welding is resumed, two consecutive samples must meet all specified tolerances.

3. The Company representative will make the decision as to the disposition of the fuel element.

F. Material

1. The fabricator shall set up quality control procedures capable of determining at any stage of manufacture the lot identity of all material, including welding filler metal. The identity must include a correlation with the required material reports and the serial number of the fuel element being fabricated.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XII. QUALITY CONTROL (continued):

F. 2. The quality control procedure shall be set up so other materials in the Seller's plant cannot be substituted for the approved material.

XIII. CLEANLINESS

A. General

1. The interior and exterior surfaces of the fuel elements shall be free from weld spatter, slag, moisture, dirt, oil, scale, paint, marking ink, pencil markings, or similar foreign matter. Also, materials containing the following elements shall not be used in the assembly except by written approval of the Company: chlorine, copper, fluorine, graphite, lead, mercury, silver, thorium.

   Note: The portions of the reactor system, in contact with cooling water, are constructed from type 304 stainless steel; therefore, the presence of any chloride-containing deposit on the elements is extremely deleterious.

2. It shall be the responsibility of the Seller to establish cleaning and inspection techniques for both the parts used in the assembly and for the complete elements commensurate with these requirements. All such procedures shall be approved by the Company, and once agreed upon, shall be changed only with its written approval.

   Note: As an indication of the quality expected once the plates are degreased and pickled, all future handling shall be by personnel wearing white gloves.

3. The use of abrasives or any procedure which removes more than 0.001 in. of aluminum from the surface is prohibited as a cleaning technique.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XIII. CLEANLINESS (continued):

B. Contamination

1. The surface contamination of a finished plate shall be less than the equivalent of that which would be obtained from 5 μg of U^{235} per square foot of surface area.

Note: With an approved quality control procedure, it shall be sufficient to inspect only the first two plates of a fabrication lot; such a procedure must provide separate facilities for rolling bare fuel cores or uranium alloy and clad plates.

XIV. INSPECTION PROCEDURES

A. Radiographic Techniques - Welds

1. Radiographic inspection of weldments shall be performed in accordance with ASTM E 142-59T, "Tentative Methods for Controlling Quality of Radiographic Testing," as modified below.

a. The x-ray source shall be located directly over the weld, with the beam making a 90° angle with the side plate and with the film held against the weld on the inside of the side plate.

b. The quality level required for radiography shall be 2% (2-2T).

c. Penetrameters shall be placed on the source side of the section being examined and shall be at both outer limits of the area of interest. They shall be held on the side of the tube at the limit of the arc to be included in the examination.

d. The density of individual films shall be between 2 and 3 in the area being examined.

e. A very fine grain type of film such as Eastman Kodak type M shall be used.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XIV. INSPECTION PROCEDURES (continued):

A. 1. f. Non-film techniques shall not be used.

g. Double-film techniques will not be permitted without special approval.

2. A system of identification of the film shall be provided.

The following information shall be provided.

(1) Name of inspecting laboratory
(2) Date
(3) Part number and/or weld number
(4) View
(5) Whether original or subsequent exposure

3. To aid in proper interpretation of radiographs, a written procedure or equivalent record shall be prepared to show the setup used to make each radiograph. This information shall accompany each radiograph and shall include:

(1) Number of film
(2) Location of each film on the radiographed item
(3) Orientation of location markers
(4) Location of radiation source, including source to film distance
(5) Kilovoltage, current, and focal spot size

4. It shall be acceptable for the Seller to furnish one standard procedure as per XIV-A-3 and to certify that an individual radiograph was made by use of the standard procedure.

5. The Seller shall certify that each radiograph was made in accordance with the requirements of this specification and that the results conform with the specified requirements.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XIV. INSPECTION PROCEDURES (continued):

B. Penetrant Inspection

1. Liquid-penetrant examinations shall be conducted as specified in ASTM E 165-60T, "Tentative Methods for Liquid Penetrant Inspection," as modified below.

   a. Only methods A-2, "Fluorescent Post Emulsified Penetrant," or B-3, "Visible Solvent Removable," shall be permitted.

   b. No cleaning other than hand wire brushing (copper or brass bristles not permitted), hand wiping with solvents, and water washing shall be permitted.

   c. All solutions shall be applied by brushing, spraying, or wiping; no dipping shall be permitted.

   d. Only dry developers shall be used with the A-2 procedure.

   e. Drying temperatures shall be limited to 160°F.

   f. When procedure B-3 is used, penetrant shall be removed by wiping with a clean cloth dampened with solvent, followed by wiping with a clean, dry cloth. Use of solvent-saturated cloths or flushing with solvents for penetrant removal is prohibited.

2. The weld area inspected shall include the face surface, any remaining weld groove, and the support tube surface to the next weld groove or for 1 in. on the ends.

3. After defect removal (section VIII-B-8), the repaired areas shall be completely reprocessed through the entire liquid-penetrant inspection to assure that all the defect has been removed.

4. During penetrant inspection, a means shall be provided to assure that the various penetrant materials are excluded from the area between the fuel plates.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XV. PACKAGING AND SHIPMENT

A. The Seller shall furnish and load the fuel elements into suitable containers that will adequately protect the elements during shipment by common carrier, including provisions for radiation safety.

B. Each element shall be shipped in an individual container.

C. Before being placed in the shipping container, each element shall be sealed in a plastic bag or similarly protected from moisture and dust.

D. Each shipping container shall be provided with a distinctive seal applied prior to leaving the Seller's premises.

XVI. ACCESS OF INSPECTOR

A. A Company's representative or inspector shall be permitted to witness any or all operations during qualification, production, or testing. The Seller shall afford the inspector all reasonable facilities for his work. All tests and inspections shall be conducted so as not to interfere unnecessarily with the operation of the Seller.

B. The Seller shall provide the Company with a schedule of expected operations so that he can schedule visits by his inspectors. This schedule shall be received by the Company a minimum of one week in advance of the operation. He shall be notified of schedule changes by telephone or telegram at least twenty-four hours before the rescheduled operation is to begin.

XVII. RADIATION SAFETY

The Seller shall be responsible for establishing safe practices for the radiation safety problems arising from the production and shipment of these elements.

Note: Pertinent information obtained by ORNL in critical experiments will be made available if desired.

The Seller should not combine two elements into a fuel assembly nor completely submerge the outer fuel element without permission from his Radiation Safety Advisor.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XVIII. RECORDS, SAMPLES, INFORMATION TO BE FURNISHED:

A. Drawings - Five copies of all drawings shall be submitted to the Company for approval. This shall include assembly drawings, subassembly drawings, and shop drawings.

1. Within two weeks of Company approval of any drawing, the Seller shall submit to the Company one certified reproducible (suitable for the dry Diazo process) of that drawing.

2. Five copies of any changes made to approved drawings must be submitted for approval.

B. Procedures - Five certified copies of all procedures shall be submitted for Company approval. This shall include (but is not limited to) procedures for plate fabrication, fuel element assembly, inspection techniques (including radiographic, hump location, and nonbond), welding, cleanliness, packaging and shipping, quality control, and qualification tests.

1. One copy of each procedure shall have sufficient contrast to be reproducible on a Xerox or similar machine.

C. Material Samples - One properly identified sample shall be submitted on each lot of:

(1) Uranium oxide
(2) Boron carbide
(3) Aluminum powder
(4) Aluminum weld rod or wire
(5) Aluminum plate and sheet
(6) Aluminum tubing

D. Material Analyses - For each batch or lot of material, five certified copies of the following analyses shall be furnished along with a certification that they comply with the requirements of this specification.

1. Chemical analysis of U_3O_8.

2. Density, surface area, and size distribution of U_3O_8.

3. Isotopic analyses of boron carbide.

4. Chemical analyses of welding rods and electrodes.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XVIII. RECORDS, SAMPLES, INFORMATION TO BE FURNISHED (continued):

E. Procedure Qualification Results - Five certified copies of all qualification test results shall be furnished the Company.

1. It shall be certified that the results of each test meet the requirements of this specification.

2. Results from the following qualification tests shall be included.

a. Welding

i. Preliminary code qualification tests.
ii. Weld quality samples for type A welds.
iii. Pullout strength samples for type A welds.
iv. Four-groove, full-size, type A test samples.
v. Type B internal test sample.
vi. Type B external test sample.
vii. Type C weld quality sample.
viii. Type C test sample.

b. Fuel Plates - Qualification test data shall be furnished for both internal and external type fuel plates.

3. Qualification test reports shall include, but are not limited to, the following data and results:

a. Weld qualification - Visual examination, penetrant examination, radiographic examination, metallographic results, pull-test results, and bend-test results.

b. Plate qualification - Visual, dimensional, radiographic, metallographic, nondestructive, and chemical results for uranium and boron homogeneity and for boron control.

F. Qualification Elements

1. One complete, full-size, inner element and one outer element certified to meet the requirements of section XI-E shall be furnished the Company before any production operations are started.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XVIII. RECORDS, SAMPLES, INFORMATION TO BE FURNISHED (continued):

G. Data Furnished with Each Element - Five copies of the following certified information shall be furnished with each fuel element.

1. A certification that the fuel element complies with the requirements of this specification.

2. Identification number of the fuel element.

3. Lot number and weight of uranium oxide in each element.

4. Lot number and weight of boron carbide in each inner element.

5. Lot numbers of all aluminum components with adequate identification as to the parts.

6. Measured values of the twelve dimensions indicated on drawings in Roman numerals.

7. Radiographs of type B welds (only original is required).

8. Inspection and metallographic examination reports on weld quality control sample, with a certification that it conforms with the specifications.

9. Results from cover plate quality control specimens (cladding thickness).

10. Analytical results from boron quality control samples.

11. Identification of all welding operators and welders.

H. Test Information with Each Element - Five copies of information must be furnished, indicating that the following inspections have been made, by whom, and summarizing the results.

1. Visual check of "as received" aluminum for blisters and elimination of all areas containing blisters.

2. Visual examination of fuel plate surfaces after forming.

Subject: SPECIFICATIONS FOR HIGH FLUX ISOTOPE REACTOR FUEL ELEMENTS

XVIII. RECORDS, SAMPLES, INFORMATION TO BE FURNISHED (continued):

H. 3. Fuel plate dimensions.

4. Core outline and minimum frame widths.

5. Visual check of rolled plate for blisters.

6. Fuel homogeneity inspection.

7. Ultrasonic inspection for nonbond.

8. Preweld visual inspection.

9. Fuel plate protrusion into weld grooves.

10. Fuel plate spacing, spot and averages.

11. Side plate thicknesses.

12. Fuel core hump locations in completed element.

13. Postweld inspection including visual, penetrant, and x-ray phases.

14. Surface contamination of fuel plates.

15. Check for cleanliness and surface conditions of final fuel elements.

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