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**SPECIFICATIONS AND FABRICATION
PROCEDURES FOR PM-2A CORE II
STATIONARY FUEL ELEMENTS**

**Materials Technology Branch
Nuclear Power Engineering Department**

Issued: May 13, 1960

**Contract No. AT(30-3)-326
with U. S. Atomic Energy Commission
New York Operations Office**

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I. FOREWORD

These specifications were prepared to aid in the procurement of stationary fuel elements for PM-2A Core II from an industrial fuel element manufacturer.

The material contained in these specifications is based on ORNL-CF-58-7-72, ORNL-2649, Oak Ridge National Laboratory, Oak Ridge, Tenn., and experience gained in the manufacture of similar dispersion type stainless steel fuel elements.

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II. ABSTRACT

Stainless steel-base fuel components of thin plate-type construction and containing a dispersion of UO_2 have been successfully employed in powering the Army Package Power Reactor (SM-1). The component is designed for radioactive service in pressurized water and consists of eighteen composite fuel plates joined into an integral unit or assembly by brazing. Specifications covering loading, materials, and processing are presented. A list of applicable drawings and the process flow diagram are included.

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III. REQUIREMENTS

- A. The fuel component is designed for radioactive service in pressurized water and once placed in operation cannot be subjected to maintenance, repair or salvage. It is imperative, therefore, that only the highest degree of quality obtainable with respect to materials of construction and workmanship be incorporated into the finished component. Hence, the component must be manufactured in strict accordance with the specifications and process flow diagram.
- B. Satisfactory performance of the reactor and of the fuel components during their operating life requires that special precautions be taken to insure the following:
 - 1. A continuous metallurgical bond between clad and core matrix material must be obtained to insure proper heat removal and freedom from potential blisters which may rupture and release fission products to the coolant.
 - 2. Uniform distribution of the fuel and burnable poison in the core of the composite plate must be achieved. Heterogeneity of these important ingredients could lead to hot spots and ultimate failure by melting. To serve as a guide, sample loading calculations are furnished in Section VIII.
 - 3. Uniformity in thickness of clad and core material must be maintained to insure protection from corrosion by the coolant and to achieve the required concentration of fuel in terms of grams of U-235/cm² over the entire area of the active portion of the fuel plate.
 - 4. The composition and processing of material must be controlled to minimize the presence of contaminants which may (a) accelerate corrosion, (b) contribute to parasitic absorption of neutrons, (c) reduce mechanical integrity of the fuel elements, (d) release gases which could promote swelling or blistering and ultimate rupture of the cladding, or (e) contaminate the surfaces of the fuel elements with traces of fissionable or fertile material that would increase the level of radioactivity in the coolant.
 - 5. The various steps of framing, cladding, shearing, machining and brazing must be carried out and inspected in a manner to preclude the presence of fissionable material at the clad-frame

interface as well as to insure that no portion of the fuel bearing core is exposed to the coolant.

- C. Fuel element manufacturing experience has demonstrated the feasibility of fabricating components which consistently meet the product standards required. Substantial assurance that the component meets these standards cannot be accomplished by nondestructive testing of random or control samples. Instead these must be combined with the establishment of and rigid adherence to proven fabrication procedures, materials inspection and cleanliness standards. Industrial utilization of the processing procedures presented does not relieve a manufacturer from any responsibility associated with the fabrication of a satisfactory product.
- D. Sufficient and proper supervisory and production control must be provided by a manufacturer: (1) to insure that all details of the fabrication procedure conforms at all times with the approved procedure, (2) to maintain rigid adherence to all specification requirements, (3) to protect personnel against human intake of airborne activity from alpha emitting UO_2 by inhalation or ingestion and to comply with the requirements of the International Commission on Radiation Protection, (4) to enforce safety measures to prevent a criticality incident, and (5) to safeguard and account for all fissionable material in accordance with the Atomic Energy Commission licensing agreement, or other arrangements with the A. E. C., as defined under the Atomic Energy Act.
- E. It will be necessary to maintain sufficient and proper records to supply pertinent data required on the fabrication of the fuel elements. During processing, positive identification of each fuel plate must be maintained along with appropriate data in order to insure: (1) proper process control, (2) inspection and quality control, (3) metallurgical history record, (4) removal of rejected material, and (5) fuel and burnable poison accountability. Records of the following items shall be maintained and copies furnished to the Contracting Agency or its authorized representative with the finished fuel elements: (1) identification of each lot of UO_2 received, (2) master log containing materials make-up and the detailed processing schedule employed in the manufacturing of each plate, (3) fuel element inspection card of critical dimensions.

To serve as a guide, the forms of the pertinent records are furnished in Section VII.

- F. In addition to the identification numbers specified in the process specifications for components and fuel elements, a symbol indicative of the manufacturer shall be added to the end boxes on each fuel element.
- G. Care must be exercised in utilizing materials such as electrodes, filler rod, cleaning agents, and lubricants that come into contact with the product during processing. Pickling of the fuel plate in any solution containing a halide ion or reducing in nature shall not be allowed subsequent to removal of the scale from the hot rolled fuel plates. The use of any processing agent that may have a deleterious effect on the finished product is prohibited.

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IV. QUALIFICATION OF FABRICATION PROCEDURE

1. Introduction

Quality control of the fuel elements is primarily attained by rigid adherence to proven fabrication procedures. Thus, specifications for the fuel elements cannot be prepared along the lines normally used for industrial products, in which quality is assured by non-destructive inspection to industry-wide standards. Consequently, the fuel element manufacturer will be required to qualify the fabrication procedure which is to be employed in the fabrication of the fuel elements. The requirements specified for the qualification fuel plates and fuel elements shall also apply to the enriched fuel plates and fuel elements.

2. Method of Qualification

Qualifications shall be performed by subjecting fourteen sample fuel plates to the tests outlined in Part 4 of this section. Approval of qualification shall be given by the Contracting Agency or its authorized representative when it has been demonstrated to the satisfaction of the Contracting Agency or its authorized representative that requirements of Part 4 have been met.

3. Preparation of Qualification Samples

^{Fourteen}
The ~~fourteen~~ sample fuel plates shall be prepared in conformance with the exact and complete fabrication procedure which is proposed to be used in the manufacture of the fuel elements and in accordance with dimensional requirements specified for long fuel plates. Depleted uranium oxide, identical in every respect with the material to be used in the fuel elements except in enrichment, shall be used in the sample fuel plates. The sample fuel plates shall be subjected to the maximum number of exactly duplicated high-temperature treatments which will be encountered in the proposed procedure for fabrication of completed fuel elements. Approval must be obtained prior to inception of manufacture of enriched fuel plates unless otherwise specifically authorized by the Contracting Agency or its authorized representative. Approval by the Contracting Agency or its authorized representative of the procedure as used in establishing qualification or of any modification thereof will not relieve the manufacturer of any responsibility for any phase of the fabrication of the fuel elements or for conformity to specification requirements.

The chemical analysis of qualification plates shall be performed only by a laboratory which has satisfactorily demonstrated its ability to analyze for uranium and boron content of stainless steel dispersion type fuel plates. Choice of a laboratory for chemical analysis work shall be approved by the Contracting Agency or its authorized representative.

4. Tests for Qualification

a. Visual Inspection

Fourteen of the sample fuel plates shall be inspected for over-all width, length, and thickness dimensions and shall be inspected for pitting, surface conditions and finish. The ~~six~~ sample fuel plates shall meet all dimensional requirements and shall not exhibit any oxide indentations or pits over 0.001 inch deep, scratches over 0.001 deep, dents over the core area, blisters, scale, or surface discoloration.

b. X-Ray Examination

The fourteen sample fuel plates shall then be x-rayed to delineate the fuel-bearing core area and to reveal any fuel segregation and voids or other internal defects. The radiographs shall be made using proper techniques with a fine-grained film such as Eastman "M", exposed and processed to yield a gamma density of 1.0-1.25 over the core area. The radiographs shall be used as the basis of measuring core length, core width, and inactive edges and ends.

The samples shall meet all dimensional requirements and shall exhibit no evidence of fuel segregation, voids and other internal defects.

c. Surface Contamination

The fourteen sample fuel plates shall be checked for evidence of alpha contamination by means of gas flow proportional counting or similar method. Alpha contamination equivalent to 0.5 micrograms of Uranium-235 per square foot of plate surface shall be the maximum allowable level of contamination. It is assumed that one microgram of Uranium-235 per square foot of surface of the fuel plate is equivalent to 150 disintegrations per minute per square foot of plate surface.

d. Homogeneity

If the fourteen sample fuel plates exhibit satisfactory homogeneity as evidenced by examination of the x-ray films, two of the ~~six~~ ^{fourteen} shall be further examined. Five miniature samples of full-plate thickness, approximately one-square inch in area, shall be sheared from each of the two fuel plates on a diagonal between core corners and approximately equally spaced, beginning two inches (2 in.) from the core-end interface and one-quarter inch (1/4 in.) from the core-edge interface. These samples shall be dissolved in their entirety and chemically analyzed for total uranium and boron contents. The results are expressed in weight per cent of specimen.

1. The uranium content of each sample expressed in weight per cent shall be within plus or minus two per cent ($\pm 2\%$) of the tested plate average.

The boron required is:

1. The boron content of each sample expressed in weight per cent shall be within plus or minus twenty per cent ($\pm 20\%$) of the tested plate average.

e. Bond Integrity

Five transverse samples equally spaced along the plate length and three longitudinal samples from each end equally spaced across the width shall be removed from two of the ~~six~~ ^{fourteen} sample fuel plates. After proper preparation and etching, the samples shall show no evidence of lack of bond at the clad-frame core-frame and clad-core interfaces upon metallographic examination at 100 diameters.

f. Clad-Core-Clad Thickness

The ten transverse samples used in "e" shall be metallographically measured to determine clad-core-clad thickness. As measured by filar eyepiece, all of the thicknesses at all points in the samples shall show compliance with specified thicknesses.

g. Total Plate Loading

Eight sample fuel plates shall be completely dissolved and analyzed for total uranium and boron content. The averages of results of duplicate analyses for each of the eight sample fuel plates shall be within the following deviations from specification:

Uranium $\pm 0.5\%$

Boron $\pm 12.0\%$

h. End Conditions

The twelve longitudinal samples used in "e" shall be examined metallographically. These samples shall show no evidence of the presence of core material in the inactive portions as dimensionally specified or of the presence of voids at the core-frame interface.

i. Fuel Fragmentation and Stringering

One longitudinal sample at least one-half inch long shall be taken from the core of each of four sample fuel plates. When examined metallographically, none of these samples shall exhibit fragmentation and stringering greater than that illustrated in Figure 1.

j. Qualification of Component Brazing

Examination of the brazed joints of a full size fuel element consisting of composite plates containing depleted UO_2 must demonstrate the ability of the manufacturer to braze fuel elements efficiently. The test fuel element shall meet all applicable dimensional requirements for brazed fuel elements as specified on the appropriate Alco Products, Inc. drawings. After appropriate sectioning of the fuel element longitudinally, the following examinations shall be made.

1. Visual Inspection for Brazing Quality

The following fillets shall be inspected:

Top Fillets

Plate No. 1
Plate No. 5
Plate No. 9
Plate No. 13

Bottom Fillets

Plate No. 4
Plate No. 8
Plate No. 12
Plate No. 16

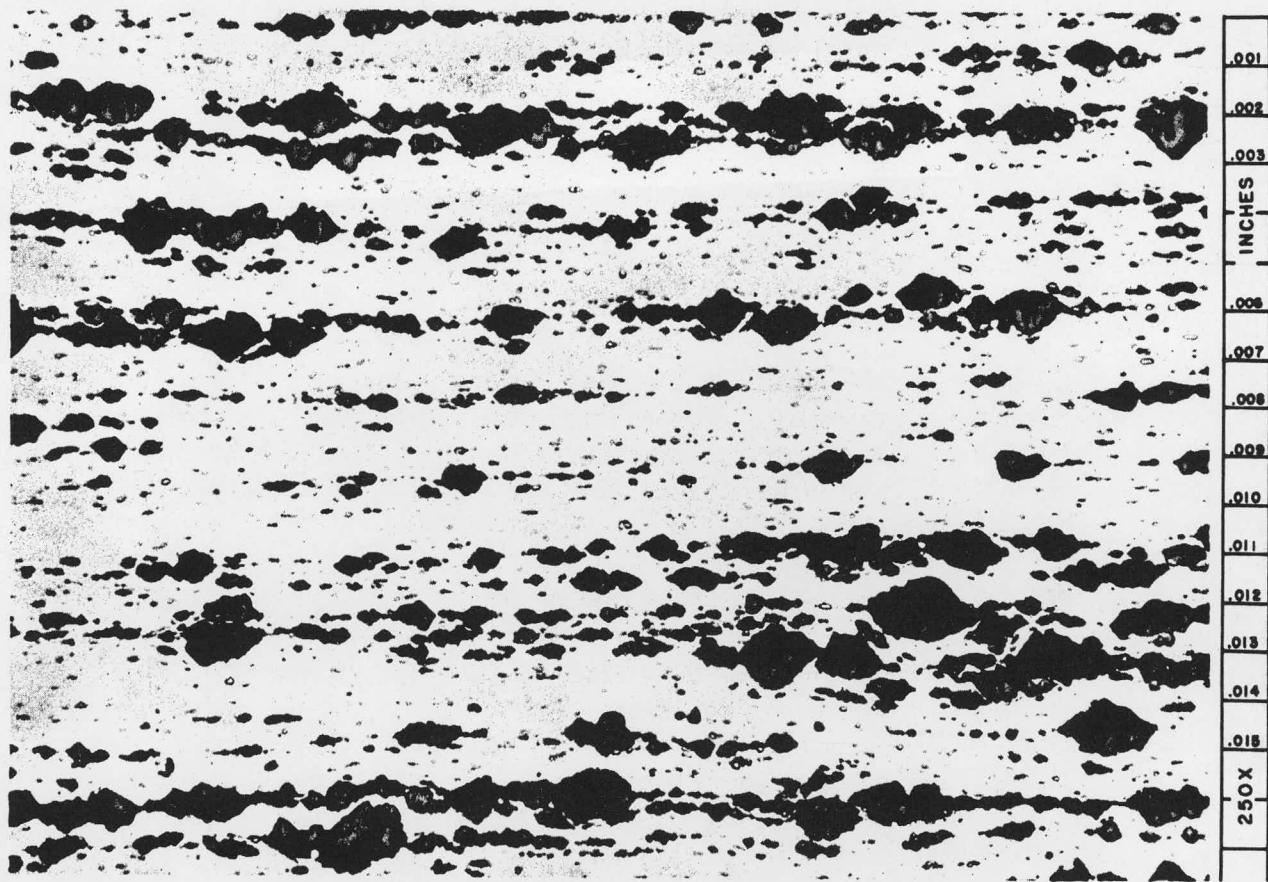


Fig. I - (Y18927) Typical Stringering and Fragmentation of UO_2 in Stainless Steel Matrix of Cold-Rolled Fuel Plate. (From ORNL-CF-58-7-72)

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The following requirements shall be met:

1. A total of two inches (2 in.) of void in the braze joints of a fuel plate will be allowed. A void is defined as any area in which the braze metal is not at least flush with the inner surface of the side plate. The presence of voids in excess of the above amount is cause for rejection.
2. Braze runout on any fuel plate in excess of sixty three thousandths of an inch (0.063 in.) from the inner surface of the side plate is cause for rejection.
3. Braze metal splatter or pitting over the active core section is cause for rejection.
4. Any pitting or wash of the fuel plate caused by reaction with the braze metal in excess of one thousandth of an inch (.001 in.) deep is cause for rejection.

2. Microscopic Examination of the Brazed Fillet

Twenty-four (24) joints shall be examined. Specimens shall be obtained from the fuel element sections containing plates No. 1 to No. 4; transverse cuts shall be made at distances of 3 inches, 12 inches, and 20 inches from the end of the fuel element. The joints shall be examined to determine the length of brazing alloy overlaying the fuel plate as measured outward from the inner edge of the side plate. Any overlay in excess of 0.063 inches is cause for rejection.

5. Conformance of Fabrication Procedure

These specifications cover materials and process required to produce completed elements. The procedural specifications are specific for manufacturing these components at ORNL and other facilities, and represent a detailed guide for fabricators. It is recognized that because of difference in equipment, fabricators may be required to modify some of the detailed procedures to arrive at the same results. Prior approval for any deviation from these specifications must be approved by the Contracting Agency or its authorized representative.

Delivery of an acceptable product, including materials, dimensions, loading, and all other requirements, remains the responsibility of the manufacturer.

The exact procedure used in fabricating the sample fuel plates which is proposed to be used in fabricating the active fuel plates shall be furnished to the Contracting Agency or its authorized representative at the conclusion of fabrication of qualification plates and at least one week in advance of the request for approval of qualification. Unless otherwise specifically authorized in writing by the Contracting Agency or its authorized representative, the procedure used in fabricating the sample fuel plates shall be strictly adhered to in fabricating the fuel plates and the fuel elements.

6. Liaison and Inspection

Free entry shall be given to the Contracting Agency or its authorized representative to all appropriate areas of the manufacturer's plant at any time during the term of the contract for fabricating the fuel elements. The manufacturer shall provide all reasonable assistance, facilities, and cooperation to the Contracting Agency or its authorized representative for determination of compliance with specification or procedure requirements or for inspection purposes as may be required and making available such testing and inspection information as may be required by ~~the Contracting Agency or its authorized representative~~.

The Contracting Agency or its authorized representative will maintain liaison with the manufacturer for the duration of the contract for the following purposes: (1) to provide necessary and reasonable technical assistance as may be required, (2) to inspect for compliance with the specifications and the approved fabrication procedure. The Contracting Agency or its authorized representative shall have the right at any time during the term of the contract to reject any and all pieces, parts, components, and products which do not meet the requirements of the specifications, or which have not been fabricated in accordance with the approved procedure, or which fail in any way to meet any of the requirements set forth in this document. Such inspection shall not relieve the manufacturer of any responsibility in any phase of fuel element fabrication or furnishing thereof.

7. Certification

Certification shall be furnished to the Contracting Agency or its authorized representative that all materials used in the fabrication and furnishing of the fuel elements are in accordance with the requirements of these specifications.

**V. CORE LOADING* SPECIFICATIONS AND A LIST
OF DRAWINGS FOR PM-2A (CORE I)**

Loading Specifications for Stationary Fuel Elements

Fuel Elements per Core	32
Fuel Plates per Fuel Element	18
Total U-235 in Stationary Fuel Elements (kg)	$17.38 \pm 0.5\%$
Total B-10 in Stationary Fuel Elements (grams)	$14.21 \pm 12\%$
U-235 per Fuel Element (grams)	543.06
U-235 per Fuel Plate (grams)	$30.17 \pm 0.5\%$
Boron-10 per Fuel Element (grams)	0.444
Boron-10 per Fuel Plate (milligrams)	$24.64 \pm 12\%$

Since the loadings are subject to revision, the manufacturer shall obtain verification from the Contracting Agency or its authorized representative that the loadings are firm.

List of Drawings for Stationary Fuel Elements (ALCO Products Inc. Drawings)

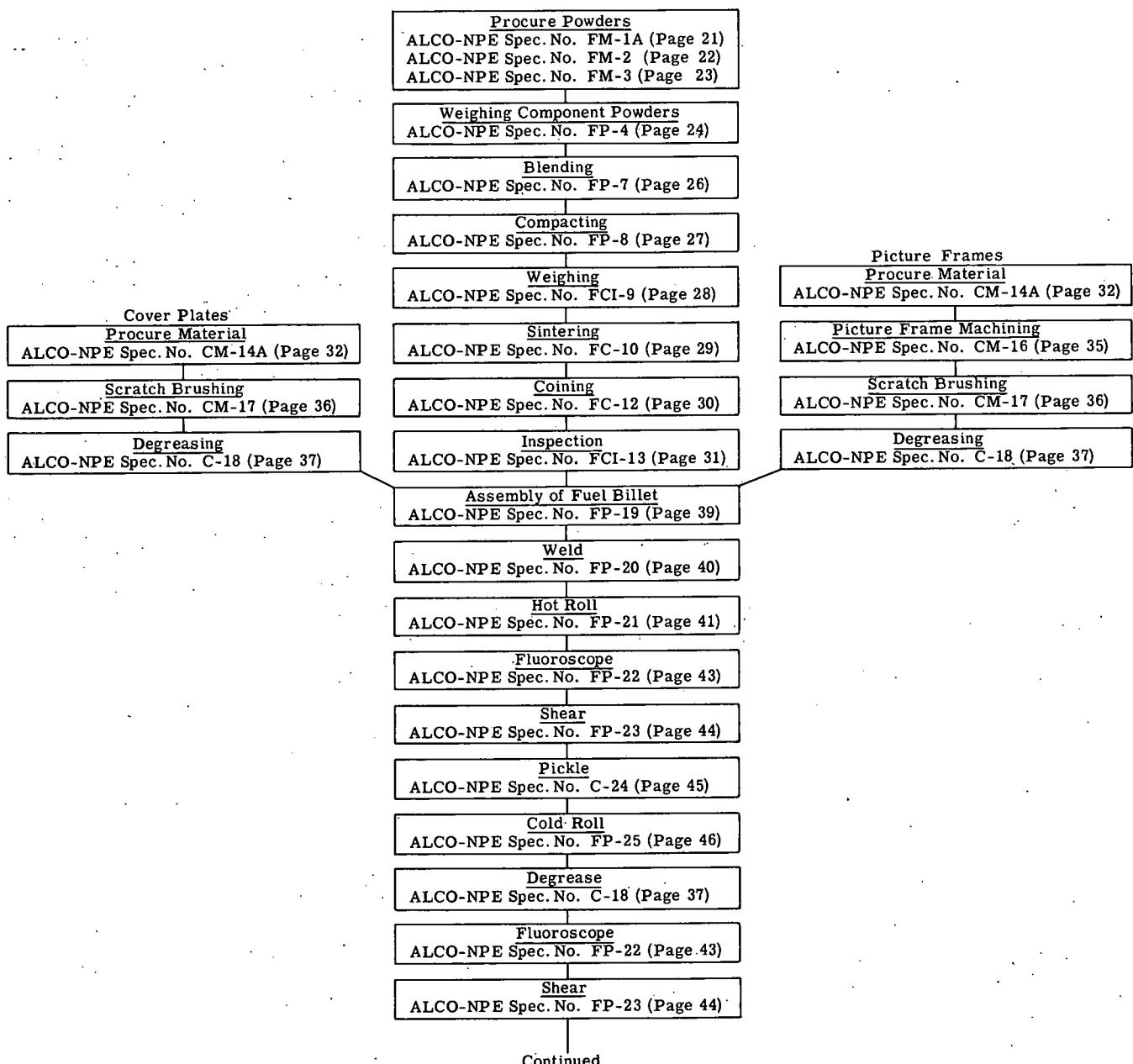
Fuel Element	R9-13-2075
Fuel Plate	D9-13-2156
	D9-13-2156-1
Fuel Plate (exploded view prior to hot rolling)	AES-342
Side Plate	D9-13-2154
Comb	D9-13-2154-1
End Box	C9-13-2022
Dowel	A9-13-2024

Drawings are included in the Appendix. Since the drawings are subject to revision, the manufacturer shall obtain verification from the Contracting Agency or its authorized representative, that the drawings contain the latest revisions and are firm.

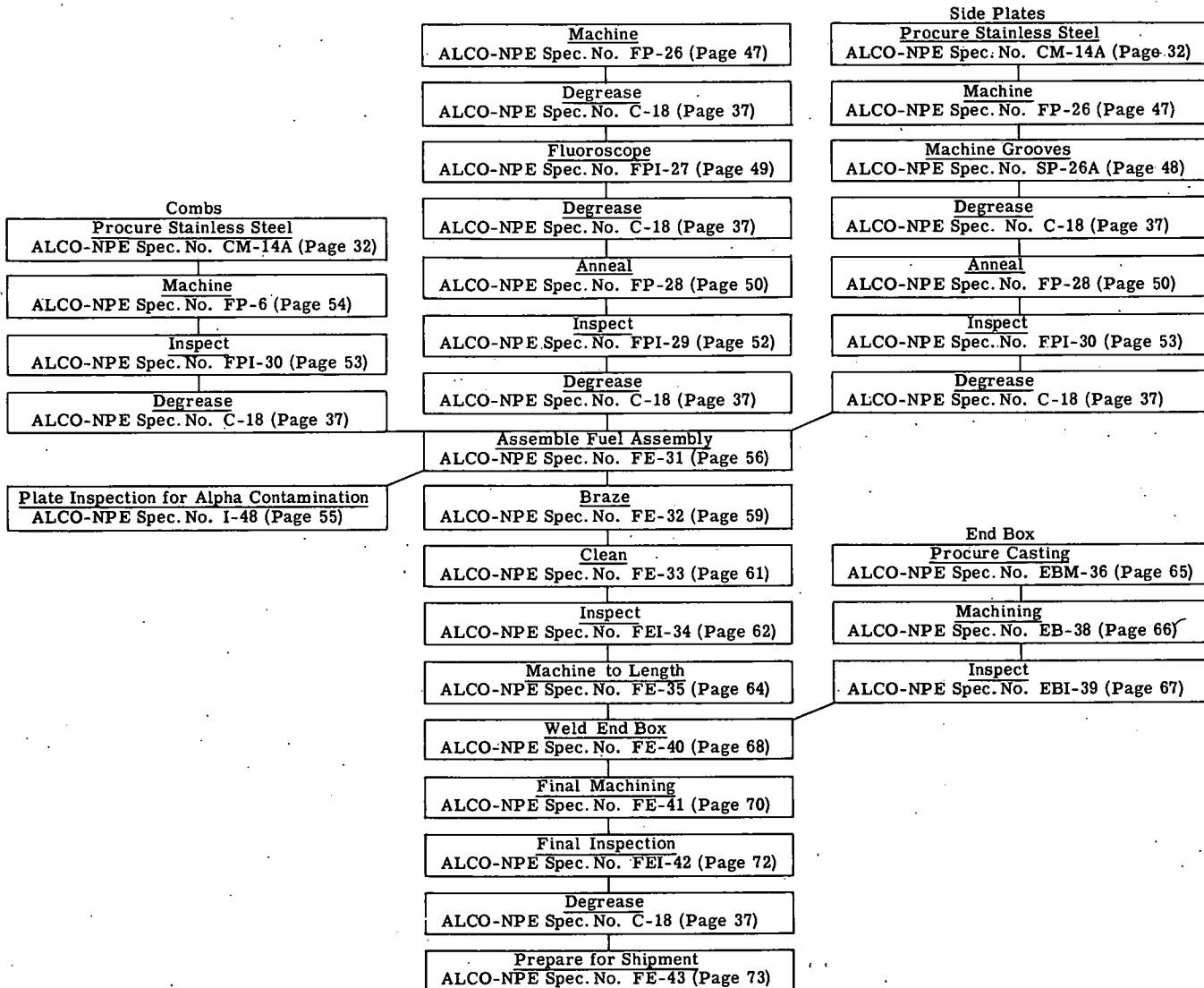
* The loadings apply to the finished product - Allowances for fabricating losses must be made by the manufacturer.

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FLOW DIAGRAM - PM-2A STATIONARY FUEL ELEMENTS



FLOW DIAGRAM - PM-2A STATIONARY FUEL ELEMENTS (CONT'D)



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PROCESS AND MATERIALS SPECIFICATIONS

ALCO-NPE Specification No. FM-1-A

Material: - Uranium Dioxide Powder ("Geneva" Type)

Purpose: - This specification covers UO_2 powder for use in nuclear reactor fuel plates of the stainless steel clad dispersion type.

Analysis: - UO_2 with a total uranium content of approximately 88 wt. %. U-235 isotopic enrichment $93\% \pm 1$ wt. %.

Specification: - This fuel shall be UO_2 powder prepared by the "Geneva" process, as originally prepared in the Y-12 Production Plant at Oak Ridge, Tennessee. The UO_2 shall contain approximately 88 wt. % total uranium and have a U-235 isotopic concentration of $93\% \pm 1$ %. Particle size shall be 44-88 μ . The UO_2 shall be free of agglomerates, platelets, rods, and clinging surface fines.

ALCO-NPE Specification No. FM-2

Material:

- Boron Carbide Powder

Purpose:

- This specification covers B₄C for use as burnable poison in the core of stainless steel dispersion type fuel plates.

Analysis:

- B₄C containing approximately 76 wt. % natural boron B-10 isotopic concentration 18.5 \pm 1.5 wt. %.

Particle Size:

- Less than 44 μ

Supplier:

- As supplied by the following, or equivalent:

Norton Chemical Company
Worcester 6, Massachusetts

ALCO-NPE Specification No. FM-3

Material:

- Stainless Steel Powder

Purpose:

- This specification covers stainless steel powder for use as matrix in dispersion type fuel elements for nuclear reactor cores.

Analysis:

- Type 304 LB stainless steel powder with .03 wt. % max. carbon content and approximately 2.5 wt. % silicon. The silicon is added primarily to prevent oxidation during preparation, however, it does result in particles with an irregular shape which leads to higher green strengths on cold pressing.

Particle Size:

- 10 to 149 μ of irregular shape

Suppliers:

- As supplied by the following, or equivalent:

Vanadium Alloys Steel Company
Latrobe, Pennsylvania

ALCO-NPE Specification No. FP-4

Title: - Weighing of Component Powders

Purpose: - This specification covers the weighing of the following component powders for use in nuclear reactor cores:

Boron Carbide

Stainless Steel

Uranium Dioxide

Process: - The component powders for each individual core are separately weighed and combined in a single blending jar. With the exception of possible losses during subsequent pressing and sintering operations, this method offers accurate accounting of the critical ingredients, U-235 and B-10, in each fuel core within the limits of the accuracy of the weighing balance. Boron carbide is the first material loaded into the blending jar and is followed by the stainless steel, and finally the uranium dioxide. This sequence permits the boron carbide and stainless steel powders to be handled in the conventional manner, thus eliminating the inconvenience of weighing these materials within a dry box, as is required during handling of finely divided UO_2 .

a. Weighing of the Boron Carbide

The burnable poison in the form of B_4C is weighed to an accuracy of at least three tenths of one per cent (0.3%). A sheet of glazed paper with glazed side up and of known weight is placed on the pan. The B_4C is added to the paper and accurately weighed. The material is then poured into a clean, wide-mouth, glass jar of four ounce (4 oz.) capacity. A camel's hair brush is used to brush any remaining particles of B_4C into the jar, which is then capped.

b. Weighing of the Stainless Steel Powder

The stainless steel powder is weighed in exactly the same manner as the B_4C . The powder is weighed to a tolerance of one hundredth of one per cent (0.01%).

It is then transferred to a blending jar containing the previously weighed burnable poison. The jar is immediately recapped.

c. Weighing of UO₂

Weighing of the fissile compound is performed within a glove box in which the atmosphere is under a slight negative pressure. The box is equipped with a balance. A weighing accuracy of three one-hundredths of one per cent (0.03%) is required.

After weighing, UO₂ is added to the jar containing the boron carbide and stainless steel powders.

After removal from the glove box, the joint between the cap and jar is sealed with masking tape. The UO₂ lot number is then marked on each jar.

Equipment:

- Gram-atic balance, or equivalent.

ALCO-NPE Specification No. FP-7

Title: - Blending Fuel Powders

Purpose: - This specification covers the blending of the powders that make up the fuel compact in order to obtain a homogeneous mixture of fuel, poison, and matrix material.

Process: - Each compact charge is blended in an individual container (a 4 ounce wide-mouth glass jar). The containers are positioned so that their longitudinal axes form a sixty degree (60°) angle with the horizontal rotating axis of a ball mill or cone blender. A two-stage blend is used. The first is dry and of two (2) hours duration. For the second, approximately one-tenth (0.10) gram (two squirts with a hand atomizer) of C. P. dodecyl or lauryl alcohol is added to each container and then blended for an additional hour. The containers are sealed with masking tape during the blending operation. Identity of the components is maintained and recorded.

Equipment: - Cone blender or ball mill.

Results of Non-Compliance: - A non-uniform blend of fuel powders will cause erratic reactivity of the core that can result in inactive cold spots and overactive hot spots. Hot spots can cause fuel plate failure.

ALCO-NPE Specification No. FP-8

Title:

- Compacting Fuel Powders

Purpose:

- This specification covers the compacting of fuel powders into a "green" compact. This is the initial operation in producing a compact for use in a fuel plate assembly. The "green" compact will be approximately ten per cent (10%) greater in thickness than the finish dimension required for fuel plate billet assembly.

Process:

- The contents of one container of blended fuel powder (ALCO-NPE Specification No. FP-7) are poured in a floating sleeve die, the jar brushed thoroughly, the powder levelled, and pressed at a minimum of thirty-three (33) tons per square inch for fifteen (15) seconds. Identity of compacts, by batches, is maintained. Batch size is determined by criticality limitations.

Lubrication:

- A minimal amount of 10 wt. per cent C. P. Stearic acid - 90 wt. per cent carbon tetrachloride lubricant is applied to the top of the die cavity and punch faces, as required. Stripes of lubricant may be applied with a 1/4 inch camels hair brush around the top and bottom of the die cavity and to the punch faces. Excessive lubrication of punch faces should be avoided since UO_2 can adhere to lubricants when the blend is poured into the die and slight segregation may occur if streaks or non-uniform coverage of die faces exists.

Cleanliness:

- Analytical chemistry laboratory standards and procedures must be adhered to at all times.

Equipment:

- Powder Compacting Press

Glove equipped dry box encloses the die providing work area for powder transfer from container to die and storage of compacts in process. The glove box is maintained at a slight negative pressure and exhausted through an absolute filter to avoid contaminating the surrounding area.

ALCO-NPE Specification No. FCI-9

Title: - Weighing of Fuel Compacts after Cold Pressing

Purpose: - This specification covers the weighing of "green" compacts (ALCO-NPE Specification No. FP-8) to determine that handling losses do not exceed allowable tolerance.

Process: - The compacts are individually weighed. A weight loss in excess of two hundred fifty milligrams (250 mg) from the charged weight is the basis for rejection.

Equipment: - Balance of more than 150 gram capacity and accuracy of ten milligrams.

Glove box.

306 028

ALCO-NPE Specification No. FC-10

Title: - Sintering of Compacts

Purpose: - This specification covers the sintering of "green" compacts (ALCO-NPE Specification No. FP-8) of dispersions for use in fuel plates. The compacts consist of UO_2 and B_4C dispersed in a matrix of stainless steel.

Process: - The hydrogen atmosphere used in heating and cooling must be maintained at a dewpoint of minus sixty degrees Fahrenheit ($-60^{\circ}F$) or better, as measured at the gas inlet of a leaktight furnace. The "green" compacts are loaded on a stainless steel screen (No. 12 mesh, type 316) in a stainless steel sintering boat (type 316) designed to permit uniform heating. If stacked two high, they are separated by stainless steel screens. The compacts are charged into the furnace cold chamber and held until the hydrogen dewpoint ^{at the furnace outlet} returns to minus thirty degrees Fahrenheit ($-30^{\circ}F$), then they are moved into the hot zone of the furnace. Sintering time is one hour and fifteen minutes ($1\frac{1}{4}$ hr) at two thousand one hundred fifty degrees Fahrenheit ($2150^{\circ}F$), plus or minus twenty-five degrees ($\pm 25^{\circ}F$). After sintering, they are moved to the cooling chamber and cooled to four hundred fifty degrees Fahrenheit ($450^{\circ}F$). From this temperature they may be air cooled to room temperature. The identity of the compacts is maintained and recorded.

Equipment: - Hydrogen atmosphere furnace capable of maintaining the above temperatures, with cooling chamber.

Source of hydrogen of the low dewpoint required.

Accurate dewpoint measuring instrument.

ALCO-NPE Specification No. FC-12

Title: - Coining of Fuel Compacts

Purpose: - This specification covers the coining of sintered fuel compacts (ALCO-NPE Specification No. FC-10) of fuel dispersion for use in fuel plates.

Process: - The sintered compact is carefully inserted into the dry-box enclosed die previously used for compacting (ALCO-NPE Specification No. FP-8) and pressed at thirty-three tons per square inch (33 TSI) for fifteen seconds (15 sec.)

Equipment: - Equipment used in ALCO-NPE Specification No. FP-8 is used for this operation.

ALCO-NPE Specification No. FCI-13

Title: - Final Inspection and Storage of Fuel Compacts

Purpose: - This specification covers the final inspection of fuel compacts (ALCO-NPE Specification No. FC-12) of fuel dispersion for use in fuel plates.

Process: - The finished compacts are visually and dimensionally inspected. Obvious flaws or surface imperfections due to nicks, cracks, spalling or breaking are cause for rejection. The finished compacts are wrapped in paper in batches and stored in a dessicator. If the storage period is more than 48 hours, a vacuum dessicator will be used.

Equipment: - Micrometers
Low Power Magnifier
Dessicator and vacuum dessicator

ALCO-NPE Specification No. CM-14-A

Title: - Cladding Material - Type 347 Low Cobalt Low Tantalum

Purpose: - This specification covers the material used for cladding, frames, combs, dowels and side plates.

Material: - The surfaces shall be free of laps, seams, scabs, or other injurious defects. The material shall be sound and free of undue stringers, entrapped foreign materials, gases or items detrimental to the continuity and strength of cladding.

Chemistry: - This steel is AISI Type 347 having the chemistry limits set forth in ASTM A-240-58T except that the cobalt shall be 0.025 max and tantalum shall be 0.01 max.

Chemical Composition: - in w/o

<u>Element</u>	<u>ASTM Specification</u>	<u>Desired Specification</u>
Carbon	0.08 max.	0.06 max.
Nickel	9.00-13.00	9.25-9.75
Chromium	17.00-19.00	18.00-18.75
Manganese	2.0 max.	1.00-1.50
Phosphorous	0.045 max.	0.030 max.
Sulfur	0.030 max.	0.030 max.
Silicon	1.0 max.	0.50-0.80
Columbium		
Tantalum	10 x C min; 1.10 max.	0.60-0.80
Cobalt	-	0.025 max.
Tantalum	-	0.01 max.
Nitrogen	0.05 max.	0.04 max.
Molybdenum	0.50 max.	0.20 max.
Copper	0.50 max.	0.20 max.

The material with the above composition limits will be used for inert gas shielded tungsten arc welding without filler metal. In addition to meeting the chemical restrictions set forth in this specification, the delta ferrite content of this material, as calculated from the Schaeffler Constitution Diagram shall be a minimum of 2% and a maximum of 10%.

ALCO-NPE Specification No. CM-14-A(Cont.)

In calculating the delta ferrite content from the Schaeffler Constitution Diagram, the following multiplying factors shall be used in computing the chromium and nickel equivalents for the production order:-

<u>Element</u>	<u>Factor</u>
Carbon	30
Manganese	1/2
Silicon	1-1/2
Chromium	1
Nickel	1
Cb + Ta	1/2
Nitrogen	30
Copper	2
Molybdenum	1

In the event that the chemistry of the heat is outside the range of the desired specification, but within the ASTM chemistry, and contains a delta ferrite content in the range of 2 to 10% as calculated from the Schaeffler Diagram, the heat will be acceptable.

In the event the chemistry is outside the desired specification limits, and below the lower limit of 2% delta ferrite, a weldability test shall be made without filler addition. Freedom from cracking shall consider the heat acceptable. The type and details of the welding test shall be as mutually agreed upon between Allegheny Ludlum and Alco Products, Inc.. Material that is not weldable, as determined by this test will not be acceptable.

Inclusion Content:-

The inclusion content of this material in the form of 1" thick sheet bar as determined by Method "B" set forth in ASTM E-45-51 shall be equal to or better than an inclusion rating of (12-5^{1/2}). This rating as determined by method "B" shall be comparable to the following method "A" rating:-

<u>Inclusion Type</u>	<u>Thin Series</u>	<u>Heavy Series</u>
Type A (Sulfide)	2	1-1/2
Type B (Alumina)	2-1/2	2
Type C (Silicate)	3	3-1/2
Type D (Globular Oxide)	3	2

The thickness of the inclusions found in 1" thick sheet bar shall not be any greater than that specified in the Inclusion Chart of ASTM E-45-51 specification.

Physical Properties:-

	0. 2% Offset	% Elonga-
Tensile Strength	Yield Strength	tion in 2"
Plate, Sheet, and Strip	75,000 psi	30,000 psi

Purchase Condition:-

Cold rolled, annealed, and pickled sheared mill plate or sheet.

Certification: -

Certification shall be furnished to Alco Products, Inc., or its authorized representative that all materials used in the fabrication and furnishing of the fuel elements are in accordance with the requirements of these specifications.

306 634

ALCO-NPE Specification No. CM-16

Title: - Machining of Picture Frames

Purpose: - This specification covers the preparation of picture frames and cover plates for use as framing and cladding of fuel plates.

Material: - The material will meet the ALCO-NPE Specification covering this application.

Machining: - Conventional machine shop practice for machining and shearing stainless steels may be utilized.

Suggested Dimensions: - Shown in exploded view of composite fuel plate prior to hot rolling.

ALCO-NPE Specification No. CM-17

Title: - Scratch Brushing of Fuel Plate Components

Purpose: - This specification covers the surface preparation by scratch brushing of components to be hot roll bonded to form the cladding of fuel plates

Process: - Picture frame and cover plate items that have been sized by rolling, machining, or other means are vapor degreased after the parts are made to size. The cover plates and picture frames are scratch brushed immediately prior to billet assembly to prepare the surface for bonding by the hot rolling process. The scratch brushing is done with a power-driven stainless steel brush. All surface contaminants are removed, i. e., slag oxides, or other adherents. An acid pickle in five per cent hydrofluoric (5% HF) - fifteen per cent nitric (15% HNO₃) bath may be used, if necessary, followed by a thorough water rinse.

Equipment: - Power-driven stainless steel brush.
Acid cleaning and rinsing equipment.

ALCO-NPE Specification No. C-18

Title: - Vapor Degreasing

Purpose: - This specification covers the degreasing of parts to prepare the surfaces for subsequent processing or to clean the finished product prior to shipment and installation in the nuclear reactor.

Process: - Vapor degreasing shall be accomplished by the following methods:

- a. All parts entering the degreaser shall be dry. Soft annealed material must be handled very carefully to avoid bending and distortion.
- b. Load parts on to racks in the condensing zone of the de-greaser so that they do not touch each other, and in such a manner as to insure complete drainage of solvents.
- c. Lower or raise finished parts in the machine at a rate not to exceed twelve inches (12 inches) per minute and immerse in vapor phase. Unfinished parts can be immersed at any rate. Spray with clean solvent during immersion time. Keep the spray nozzle below the vapor until condensation ceases, three to five minutes (3 to 5 min). Parts shall be completely dry before removing from the de-greaser. After removal of finished fuel elements, clean dry air is carefully blown through the assembly to remove any solid debris. Finished fuel elements shall be degreased horizontally.

Bath Requirements: -

1. Perchloroethylene - operate between two hundred fifty and two hundred sixty degrees Fahrenheit (250-260° F).
2. Trichloroethylene - operate between one hundred eighty-five and one hundred ninety degrees Fahrenheit (185-190° F).

NOTE: The above solvents shall contain a neutral inhibitor to prevent acid formation due to hydrolysis. Other types of inhibitors are not permitted.

ALCO-NPE Specification No. C-18 (Cont.)

3. The solvent shall be checked at least weekly for boiling point. Solvent shall be completely replaced when the boiling point of perchloroethylene exceeds two hundred sixty degrees Fahrenheit (260⁰F) or boiling point of trichloroethylene exceeds one hundred ninety-five degrees Fahrenheit (195⁰F).

Safety: - The solvents are hazardous. Every precaution shall be taken to protect personnel from the solvents which have a toxic effect when inhaled.

Equipment: - Vapor Degreaser

ALCO-NPE Specification No. FP-19

Title: - Assembly of Fuel Plate Billets for Hot Rolling

Purpose: - This specification covers the assembly of the components as the first step in the fabrication of fuel plates.

Process: - The fuel compact is inserted into the hole in the cleaned picture frame and this assembly is sandwiched between two cleaned cover plates. One edge of the sandwich is identified with a grease pencil in a manner to indicate the orientation of the fuel compact. This will establish the direction of rolling.
The assembly is "fixed" by spot welding. The welds are made over the picture frame area and within one-eighth inch (1/8 in.) of the edges of the assembly. These are excess material areas that will be removed during subsequent operations. Identity of the compact is retained and recorded. In-process storage exceeding 48 hours must be in a vacuum dessicator. An ordinary dessicator may be used for storage periods under 48 hours.

Equipment: - Minimum of 25 KVA spot welding machine.

ALCO-NPE Specification No. FP-20

Title: - Edge Welding of Fuel Plate Components

Purpose: - This specification covers the edge welding of fuel plate components for positive locking to prevent shifting during the subsequent hot rolling operation.

Process: - The edges of the cover plates are welded to the picture frame by the tungsten inert gas method. Filler metal is not ordinarily added. The corners of the fillet are not welded for a distance of one-quarter inch (1/4 in.) along each edge. This is to permit the escape of entrapped gases during the initial hot rolling passes. The direction of rolling may be identified by the addition of stainless filler metal to form a projection at the end identified by previous marking. Identity of the billets must be retained and recorded. In-process storage exceeding forty-eight hours (48 hrs.) must be in a vacuum dessicator. For storage of shorter duration, a plain dessicator may be used.

300-40

ALCO-NPE Specification No. FP-21

Title: - Hot Rolling of Fuel Plates

Purpose: - This specification covers the hot rolling of the assembled and welded components (ALCO-NPE Specification No. FP-20) to obtain clad and frame to core bond and to each other and to dimensionally prepare the resultant composite fuel plate for subsequent processing.

Process: - The billet is hot rolled to ten thousands of an inch plus or minus two thousandths ($0.010 + .002$ inches) above the final thickness of the cold rolled fuel plate. The first two (2) passes, each at ten per cent (10%) reduction, will serve to seat the components. Subsequent reductions may be increased to a maximum of thirty per cent (30%) per pass. The work is rotated about both the transverse and longitudinal axes between each pass. The position and direction of rolling is determined from the stainless steel projection (ALCO-NPE Specification No. FP-20). A minimum of four (4) inches of inactive material is required beyond the ends of the fuel. The excess may be trimmed as required to fit the furnace length and facilitate handling. The dispersion-type core can be delineated from the inactive end material by a difference in heat color.

Heating is done in a muffle furnace using a hydrogen atmosphere with dewpoint of minus sixty degrees Fahrenheit (-60°F) at the furnace inlet. The flow must be adequate to prevent oxidation in the furnace. The furnace must be capable of maintaining a temperature of twenty-one hundred degrees Fahrenheit (2100°F) plus or minus twenty-five degrees ($+25$) over a muffle length of thirty-two inches (32 inches). The billets are heated in a furnace at twenty-one hundred degrees Fahrenheit (2100°F) for at least twenty minutes (20 min.) prior to the first pass and reheated for at least two minutes (2 min.) between subsequent passes. The thickness is checked with a micrometer near the end of the fabrication schedule. After the final pass, the rolled billet is replaced in the muffle for a five minutes (5 min.) anneal, and then is air cooled.

The fuel compact identification must be retained throughout the processing. After the fuel plates are cooled, the identification is metal stamped on the inactive section at either end near the edge of the plate and recorded.

ALCO-NPE Specification No. FP-21 (Cont'd.)

Rolls, tables, and furnace hearth or muffle must be kept clean of oxides or other foreign material that may adhere to the work surfaces. If foreign material is trapped between the rolls and the billet, it is forced into the billet and the cladding continuity may be broken or its thickness altered. Surface imperfections in excess of one thousandth of an inch (0.001 in.) in the finished fuel plate are cause for rejection. Therefore, extreme care must be exercised during the rolling operation.

Rolling lubricants are not used as a precaution to avoid contaminating the cladding which may result in premature failure during reactor operation. Roll parallelism must be maintained and the billets fed perpendicularly to the rolls to avoid rainbowing of the rolled billets.

Equipment:

Hydrogen atmosphere furnace capable of maintaining the above temperatures, and leak tight muffle.

Source of hydrogen of the dewpoint required.

Accurate dewpoint measuring instrument.

Rolling mill of a capacity to produce straight plates of uniform thickness.

ALCO-NPE Specification No. FP-22

Title: - Composite Plate Core Layout

Purpose: - The hot rolled plates are fluoroscoped to delineate the core section for determination of shearing and/or machining boundaries to remove the excess inactive material from the edges and ends.

Process: - While being fluoroscoped, a slotted picture frame type template is centered over the core and used to mark scribe lines for shearing and/or machining. The template contains slots at the dimensions to be marked on the plate and the slot edges are used in scribing the cutting lines.

Shearing Layout - The shearing template shall allow excess material required for subsequent operations, i. e., cold rolling and machining. The accuracy of the scribed lines that are used for the shearing operation prior to the final machining is such that the sheared edge may be used for locating the plates in the final machining fixture.

After hot rolling, the suggested template locates scribe lines one-half inch (1/2 in.) beyond the sides of the fuel core and three inches (3 in.) beyond the ends, for both long and short plates.

After cold rolling, the suggested template locates scribe lines allowing a sheared plate width approximately .085 inches wider than the final machined plate. The lengths are sheared to provide approximately 1/64 inch excess inactive material to be removed in final machining.

Identification - The identification prior to the cold rolling operation is heavily metal stamped just inside the scribed lines at the same end of the plate that had been previously identified. The identification prior to the final machining operation is inscribed with a Burgess Vibro tool in numbers about three-eighths inch(3/8 in.) high and far enough from the centerline to prevent obstruction by combs that may be used at the plate ends in the fuel element.

Equipment: - 175 KVP X-ray machine with fluoroscope screen.

ALCO-NPE Specification No. FP-23

Title: - Shearing

Purpose: - This specification covers the shearing of material or components used in the manufacture of fuel elements.

Process: - Guides, jigs, fixtures, and hold-downs conducive to facilitating the operation are permitted. Extreme care must be exercised when handling clad materials so that the cladding is not damaged. Cladding material thickness is of the order of five thousandths of one inch (0.005 in.). Therefore, all contacting surfaces must be smooth and free of protrusions or sharp edges which may inadvertently be the cause of cladding destruction, indentation, or weakening. Hold-down unit pressures must be such that the cladding is not destroyed or weakened. Good housekeeping must be practiced at all times to avoid cladding pickup of foreign items such as dirt, chips, slivers, etc.

Proper knife clearances must be utilized to avoid tearing or slivering of the sheared edge.

Equipment: - Shear

ALCO-NPE Specification No. C-24

Title: - Pickling

Purpose: - This specification covers the pickling of stainless steel fuel element components to remove oxides and other surface contaminants or adherents that may interfere with subsequent processing, or that are detrimental to the final product. The following pickling solution is not to be used for pickling the composite plates after flatten annealing or brazing.

Process: - The work is pickled in an aqueous solution of fifteen per cent nitric acid and five per cent hydrofluoric acid (15% HNO_3 -5% HF) at about one hundred thirty-five degrees Fahrenheit (135°F) until the surface is clean. After pickling, the work is immediately and thoroughly washed with water to remove all traces of acid. The time required for pickling will increase as the acid is depleted. Periodic checks of the acid concentration shall be made.

Health Hazard: - This acid solution will attack the human body very rapidly; therefore, the pickling tanks should be well hooded and exhausted. Protective clothing, helmets, and gloves are a prerequisite to entering the pickling area. Water showers and eye sprays are to be provided for rapid removal of any acid that may be accidentally splashed on the personnel.

Safety: - Some acid concentrations react violently; therefore, the mixing sequence will be to put the measured proportion of water required in the pickling tank and then slowly add the required amounts of acids while stirring the bath.

Equipment: - Acid resistant tanks. Carbon block or plastic lines tanks are recommended.

ALCO-NPE Specification No. FP-25

Title: - Cold Rolling of Plates

Purpose: - This specification covers the cold rolling of plates to final size.

Process: - Care must be exercised to avoid excessive fragmentation and stringering of the dispersion particles in the composite plates. Therefore the maximum permissible reduction per pass is one thousandth of an inch (0.001 in.). Small reductions permit the flow of matrix material so that the majority of the deformation occurs within the matrix, minimizing fragmentation of the dispersed particles. The composite plate thickness is measured over the section containing the dispersion. The length of the core is also important, and since length and thickness vary inversely percentagewise, the length tolerance generally becomes the limiting factor. The fuel plate shall be rotated about the transverse and longitudinal axes between passes. Roll parallelism and good work feeding are important requirements for producing straight plates.

Extreme care must be exercised when handling clad materials so that the cladding is not damaged. Cladding material thickness is five thousandths of an inch (0.005 in.). Therefore, all contacting surfaces must be smooth and free of protrusions or sharp edges which may inadvertently be the cause of cladding destruction or weakening. Good house-keeping must be practiced at all times to avoid cladding damage by foreign items such as dirt, chips, slivers, etc. being entrapped during rolling.

Equipment: - Rolling Mill capable of producing straight plates of uniform thickness.

ALCO-NPE Specification No. FP-26

Title: - Final Machining of Fuel Plates or Side Plates

Purpose: - This specification covers the final machining of fuel plates. The plates are machined to length and width prior to assembling into the fuel assembly grooved side plates to form a fuel element. The side plates are final machined to length and width prior to groove milling.

Process: - The plates may be stacked for straddle or duplex milling to width, and side ~~and~~ milling to length. The stacked plates are sandwiched between one-eighth inch (1/8 in.) thick aluminum cushion plates that protect the plates from scratching and deformation when locked in the machining fixture. A bridge-type fixture bolted to the machine table is used to hold the plates during machining. Removable stops are used for positioning the plates during the bolting of the bridge. After vapor degreasing, the machined plate edges are lightly deburred by hand filing. Special care is taken to prevent rounding of the edges. Plates are final machined, including tapers and holes where required.

Lubricants: - Standard stainless steel cutting lubricants are acceptable.

Cutting Tools: - Carbide or carbide tipped cutting tools are recommended whenever practical for tool life and to minimize the possibility of smearing the cuts with cutting tool material that may have a high neutron cross section and/or long half life.

Equipment: - Milling machine.

ALCO-NPE Specification No. SP-26A

Title: - Side Plate Grooving

Purpose: - This specification covers the machining of grooves in the stainless plates (ALCO-NPE Specification No. FP-26) to be used as the side plates of the fuel element (ALCO-NPE Specification No. FE-31).

Process: - Conventional machine shop practice for the machining of stainless steels may be used to groove the side plates per the appropriate drawing. Both gang milling and planing have been used. Special care is exercised to insure that the dimensions between the grooves and edges of the side plates are correct. Full plate length vacuum chucks have been used to hold the work during machining. Carbide tipped cutting tools are recommended.

Lubrication: - A heavy sulfur-base cutting oil, or equivalent may be used for lubrication.

Equipment: - Milling machine or planer. Vacuum chuck.

ALCO-NPE Specification No. FPI-27

Title: - Machined Fuel Plate Fluoroscopic and Visual Inspection

Purpose: - This specification covers the fluoroscopic inspection of the fuel plates to determine their acceptability with respect to core width and length and edge and end cladding width.

Process: - Suggested method of fluoroscopic inspection is by means of a template centered over the core. The template contains slots over the critical areas of core width and length, marked to show maximums and/or minimums on a go-no-go basis. The acceptability of the plate is determined with respect to core width and length, and edge and end cladding width.

Fuel plates that fail this inspection normally are radiographed as a positive check on dimensions. Core length, width, and width of edge and end cladding are measured directly from the X-ray film. Plates which do not meet dimensional requirements are rejected. Every 25th plate is radiographed to determine the reproducibility of the process with respect to homogeneity of the dispersion.

This inspection step also includes the visual inspection of the fuel plates. The surfaces are inspected for defects. Indentations, pits, rolled-in scale and scratches deeper than one thousandth of an inch (0.001 in.) are cause for rejection. Dents and blisters are also cause for rejection.

Safety Hazard: - X-rays are hazardous and over-exposure of the human body will result in severe burns. Leakage about the machines must be below acceptable levels. Regular monitoring by the Health Safety Department is required.

ALCO-NPE Specification No. FP-28

Title: - Annealing of Fuel Plates and Side Plates

Purpose: - This specification covers the flatten annealing of cleaned machined plates (stainless steel or stainless clad) ALCO-NPE Specification No. C-18) to facilitate assembling into the proper array and to meet plate spacing dimensions in the brazed fuel unit. The plates are stack annealed in a clamping jig.

Process: - Fuel Plates

Each fuel plate is covered on one side with a thin coat of a mixture containing one part by volume of Fisher Precisionite levigated alumina and ten (10) parts of water. A three (3) inch camel's hair brush is used to apply an even coating. ^{SPRAYING MAY NOT BE USED} The coated fuel plates are allowed to dry for at least fifteen (15) minutes.

Approximately twenty-five (25) fuel plates are stacked together with the coated sides adjacent to the uncoated sides. The stack is loaded in a jig composed of two platens bolted together to clamp the plates. The inner surface of the platens are coated with a mixture containing one part by volume of Fisher levigated alumina and ten parts water. The loaded and tightened assembly is dried in an oven at three hundred thirty degrees Fahrenheit (330°F) for a minimum of sixteen (16) hours.

This assembly is annealed in a leak tight muffle furnace using a hydrogen atmosphere from a leak tight feed line at twenty-one hundred degrees (Fahrenheit plus or minus twenty-five degrees Fahrenheit (2100°F + 25°F). A hydrogen dewpoint of minus eighty degrees Fahrenheit (-80°F), as measured by an Alnor dewpointer at furnace inlet, must be maintained. The load is charged into the furnace held at under five hundred and seventy degrees Fahrenheit (570°F).

Caution - An inert gas purge must be used in the furnace until a temperature of twelve hundred degrees Fahrenheit (1200°F) is reached to avoid the possibility of attaining an explosive mixture of hydrogen and air. The temperature is raised to twelve hundred degrees Fahrenheit (1200°F) at the rate of five hundred forty degrees Fahrenheit (540°F)

per hour. At this temperature, the inert gas atmosphere is replaced by hydrogen. A flow rate sufficient to bright anneal stainless steel is required. The temperature is raised to twenty-one hundred degrees Fahrenheit (2100°F) at a rate of approximately five hundred and forty (540) degrees per hour. The plates are held at twenty-one hundred degrees Fahrenheit (2100°F) for two hours, and then furnace cooled to approximately five hundred seventy degrees (570°F). At this temperature, the hydrogen atmosphere is replaced with an inert gas purge. The assembly is then removed from the furnace and air cooled. After disassembly, the fuel plates are scrubbed under flowing water to remove the alumina. Care is exerted in this scrubbing treatment to avoid distortion of the plates.

Side Plates

Grooved side plates are annealed as above with the following exceptions:

1. The individual side plates are separated by type 304 L stainless steel shim stock approximately thirty thousandths of an inch thick (0.030 in.)
2. The alumina mixture is applied to both sides of the shim stock. The side plates are not coated because of the difficulty in removing the alumina from the grooves.
3. A maximum of fifteen side plates are stacked with the alumina-coated shims between each plate.

Equipment:

Furnace capable of attaining (at a controllable rate not exceeding $540^{\circ}\text{F}/\text{hr}$) and holding $2100^{\circ}\text{F} \pm 25^{\circ}$ with hydrogen atmosphere of -80°F dewpoint and helium source.

Accurate dewpoint measuring instrument.

Safety:

CAUTION - At temperatures under twelve hundred degrees Fahrenheit (1200°F), hydrogen will form violently explosive mixtures with air; therefore, purging of furnaces under this temperature must not be done with hydrogen gas.

ALCO-NPE Specification No. FPI-29

Title: - Final Inspection of Fuel Plates

Purpose: - This specification covers the inspection of finished stainless steel clad fuel plates prior to cleaning and assembly into a fuel element.

Process: - The fuel plates are visually inspected. Oxide indentations, pits, and/or scratches deeper than one thousandth of an inch (0.001 in.) are cause for rejection. Dents, blisters, and presence of any foreign material on the surface are also cause for rejection. The fuel plates shall be dimensionally inspected per the appropriate drawing.

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ALCO-NPE Specification No. FPI-30

Title:

Comb or Grooved Side Plate Inspection

Purpose:

This specification covers the visual and dimensional inspection of finished stainless steel combs or side plates prior to assembly into a fuel element.

Process:

Side Plates - subsequent to grooving and annealing, each plate is visually and dimensionally inspected. The plate groove depths are determined either by gauge wire with a micrometer or by a thin roller attached to a dial indicator. The groove separations which govern fuel plate spacing in the fuel element are measured with a disc type micrometer. Failure to meet groove depth, width, and/or separation is cause for rejection.

Combs - subsequent to machining, comb groove width and location are inspected in the same manner as the grooved side plates.

ALCO-NPE Specification No. FP-6

Title: - Comb Machining

Purpose: - This specification covers the machining of stainless steel combs to be used at the ends of the fuel plates in the fuel elements. The combs are assembled in the fuel assembly prior to brazing.

Process: - Combs are normally made from 3 in. x 1 in. + $1\frac{1}{16}$ in. material .050 in. + .003 in. thick. The length is milled to final size. The width is milled oversize (1/4 inch) to provide sufficient stock for holding during the slotting operation. Slotting is performed on a milling machine with a screw-slotting cutter. A group of fifteen (15) or twenty (20) combs is held by the excess material on the width in a precision vise mounted on the table of the milling machine. Each slot is machined individually. After complete slotting, the pieces are mounted in a precision vise and machined to remove the excess width stock.

Equipment: - Milling Machine

ALCO-NPE Specification No. I-48

Title: - Plate Inspection for Alpha Contamination

Purpose: - This specification covers the sampling and alpha counting of cleaned fuel plates, prior to assembly for brazing, to determine the level of surface contamination by Uranium-235.

Process: - Sampling - every tenth plate shall be cleaned and counted.

Counting - the plate shall be checked for alpha contamination by means of gas flow proportional counting or a similar method. Alpha contamination equivalent to 0.5 micrograms of Uranium-235 per square foot of plate surface shall be the maximum allowable level of contamination. It is assumed that one microgram of U-235 per square foot of surface of the fuel plate is equivalent to 150 disintegrations per minute per square foot of plate surface. In addition, the plate identity and amount of alpha contamination will be recorded and this information forwarded to the Head of the Health Physics Group of the Contracting Agency or its authorized representative.

ALCO-NPE Specification No. FE-31

Title: - Assembly of Fuel Plates into Side Plates

Purpose: - This specification covers the assembly of fuel plates, combs, and grooved side plates into a fuel assembly. The components are assembled into a jig, braze and stop-off material is applied as required, and then the assembly is brazed. The same jig is used for both assembly and brazing; therefore the material used in constructing the jig should have the same expansion characteristics as the component material. Coast Metals N.P. braze metal powder is used for brazing. Colmonoy Nicrobraz Cement for binding, and Colmonoy Green Stop-off to restrict the flow of the braze metal on to the fuel plates.

Process: -

- a. Two side plates, with grooved sides facing each other, are placed inside the supports of the open-end-up U-shaped jig and centered longitudinally. The distance between matching groove bottoms should provide for the fuel plate width and five thousandths of one inch (0.005 in.) braze metal clearance at each edge between the fuel plate and groove bottom. To allow for flexibility in assembly, the inside dimension of the "U" supports is normally about .100 inch larger than the finish width of the assembly. A shim plate is used between each side of the jig and the side plate to compensate for the gap. A stop, usually a removable comb holder, is used at one end of the jig to position the short fuel plates longitudinally. The removable comb holder is attached to a side plate stop which serves to locate the front ends of the side plates and long fuel plates.
- b. A fuel plate is inserted from the open end of the jig into the bottom groove of the side plates and positioned snugly against the stop.
- c. The jig is tilted about the longitudinal axis approximately twenty degrees (20°).
- d. The dry Coast Metals N.P. braze metal is applied to the plate joint by gravity from a stainless steel pointed tube resembling the barrel of a mechanical pencil. It is important that the braze metal be confined to the inactive edge of the fuel plate and not preplaced on the cladding.

surface above the fuel core. Since the minimum specification of the width of the inactive stainless steel edge of the fuel plate is one-tenth of an inch (0.100 in.), and twenty-five thousandths of an inch (0.025 in.) is the maximum distance the plate is inserted in the plate groove, only a seventy-five thousandths of an inch (0.075 in.) wide strip of inactive stainless steel remains for preplacement of braze powder. It is recommended that the width occupied by the braze powder be less than sixty thousandths of an inch (0.060 in.).

- e. The dry braze metal powder is cemented into place with Colmonoy Nicrobraz Cement. A nineteen (19) gauge hypodermic needle on a five cubic centimeter (5 c. c.) syringe is used to apply the cement to the fuel plate adjacent to the braze metal fillet. The cement is allowed to dry for thirty seconds (30 sec.)
- f. A one quarter inch (1/4 in.) wide strip of Colmonoy Green Stop-off is applied with a camel's hair brush directly adjacent to the braze metal on the active portion of the fuel plate. The stop-off is used to prevent the braze metal from flowing laterally onto the stainless steel cladding of the active core section during the subsequent brazing operation.
- g. The jig is tilted about the longitudinal axis in the direction opposite step "c" and the above steps are repeated for the opposite fuel plate to side plate joint. The braze materials are applied to one side of the fuel plate only.
- h. A comb is placed in the comb holder, and the braze metal, cement, and stop-off are applied in succession to the comb-to-long plate joint.
- i. A short plate is inserted in the second row of side plate grooves and firmly placed in the comb groove.
- j. Steps "d" to "g" are repeated with the addition of filling the comb-to-plate joint with braze metal, cement, and stop-off.

- k. The process is repeated, inserting plates from bottom to top until all of the short fuel plates have been readied for brazing.
- l. The second comb is attached to the unit prior to inserting the top long fuel plate into the side plate grooves. All comb-fuel plate joints are filled with braze metal, cement, and stop-off.
- m. The joints of the top long fuel plate are prepared in the same manner as the bottom long plate.
- n. The comb holder is removed from the jig and the complete jig and assembly rotated 90 degrees. The brazing materials are then applied to the long fuel plate-comb joint.
- o. A one-half inch (1/2 in.) wide strip of Colmonoy Stop-off is made across the side plate inside the assembly one-half inch (1/2 in.) beyond the short fuel plates. This strip prevents the braze metal from flowing to the ends of the side plate during brazing, which may cause difficulty in welding end adapters to the brazed fuel assembly.
- p. The fuel assembly is assigned a number and the relative positions of the fuel plates within the fuel assembly are recorded.

Caution:

- a. Care must be exercised to avoid the application, flow, and/or contamination of the cladding surfaces above the fuel by the braze metal. Care must also be exercised to avoid contamination by braze metal of the ends of the fuel element. This will interfere with the attachment, by welding, of the end brackets. The brazing metal shall be free of boron. Shim stock or jig areas that come in contact with the fuel assembly shall be coated with either Colmonoy Green Stop-off or Fisher Precisionite levigated alumina that will act as the separating agent.

ALCO-NPE Specification No. FE-32

Title: - Brazing of Fuel Assemblies

Purpose: - This specification covers the brazing of the assembled fuel assembly prior to attachment of the end boxes.

Process: - Brazing of fuel assemblies is accomplished in a furnace equipped with a leak-tight muffle for maintaining a dry hydrogen atmosphere and capable of maintaining a maximum gradient of five degrees Fahrenheit (5°F) along the entire fuel assembly length at the brazing temperature.

Calibrated chromel-alumel thermocouples are attached (one to the front and the other to the rear) to the assembly. Each thermocouple is checked at room temperature prior to acceptance. The hot junctions are positioned two inches (2 in.) in from the ends of the short fuel plates. One junction is placed at each end of the fuel assembly between the middle two fuel plates.

Stainless steel heat baffles may be used around the charge to minimize temperature gradients during the heating and cooling cycle. The jig containing the fuel assembly, complete with thermocouples, is placed in the furnace at a maximum temperature of five hundred seventy degrees Fahrenheit (570°F). A dry inert gas atmosphere, with a minimum dewpoint of minus forty degrees Fahrenheit (-40°F) as measured by an accurate dewpoint measuring instrument at the inlet, is introduced. Stainless steel thermal reflector shields may be used at the ends of the jig to minimize thermal gradients along the length of the fuel element.

The furnace temperature is raised to twelve hundred degrees Fahrenheit (1200°F) at a rate not to exceed three hundred seventy degrees (370°F) per hour. The furnace is held at this temperature until the temperature gradient, as measured by the work thermocouples, is less than forty-five degrees Fahrenheit (45°F). At this time, dry hydrogen with a dewpoint of at least minus eighty degrees Fahrenheit (-80°F) is introduced and the inert gas purge discontinued. The furnace temperature is raised to eighteen hundred thirty-five degrees Fahrenheit (1835°F) and held until the gradient, at the work thermocouples, is less than eighteen degrees Fahrenheit (18°F) and the

outlet hydrogen dewpoint is at least minus fifty degrees Fahrenheit (-50°F). The furnace temperature is raised to two thousand ten degrees Fahrenheit (2010°F) and held until the fuel element temperature gradient is less than five degrees Fahrenheit (5°F). Above this temperature, the furnace temperature is raised slowly by careful manual control. Temperature readings are taken on both thermocouples every minute. The temperature gradient is maintained as low as possible, with a maximum of five degrees Fahrenheit (5°F). When the work thermocouple temperatures reach two thousand seventy-one degrees Fahrenheit (2071°F), the furnace is shut off. The total time for the load above two thousand sixty-six degrees Fahrenheit (2066°F), as measured by the thermocouples, should not exceed eight minutes (8 min.). The brazed fuel assembly is furnace cooled to five hundred and seventy degrees Fahrenheit (570°F), at which temperature the furnace atmosphere is replaced with an inert gas purge. After thorough purging, the furnace is opened and the assembly is removed from the furnace and air cooled to room temperature.

After the brazing operation, each assembly is identified with numbers approximately one-half inch (1/2 in.) high; A Burgess Electric Vibro Tool with a tantalum-carbide tipped point is used for marking. The fuel assemblies are marked with the assigned number on a side plate near the top end and near the top side of the fuel assembly. The last fuel plate inserted determines the top of the fuel assembly.

Equipment:

Hydrogen atmosphere furnace with a 5°F maximum temperature gradient in the working zone, and capable of attaining and maintaining, at the above rates, the brazing temperature. Hydrogen atmosphere of -80°F dewpoint, and inert gas purge. Accurate dewpoint measuring instrument.

Safety:

Caution: At temperatures under twelve hundred degrees Fahrenheit (1200°F), hydrogen will form violently explosive mixtures with air; therefore, purging of furnaces under this temperature must not be done with hydrogen gas.

ALCO-NPE Specification No. FE-33

Title: - Cleaning of Brazed Fuel Assembly

Purpose: - This specification covers the cleaning of brazed fuel assemblies (ALCO-NPE Specification No. FE-32) to remove the stop-off residue that was used to avoid the indiscriminate spreading or flowing of brazing material during the furnace brazing operation.

Process: - The fuel assemblies are scrubbed under water with stainless steel brushes. The residue is scrubbed from the water channels using a one-eighth inch (1/8 in.) diameter stainless steel brush. Extreme care must be exercised to avoid damage to the fuel plate cladding by scratching, nicking, or removal by the abrasive action of the wire brush. Extreme care must also be exercised to avoid mechanical distortion of the fuel assembly or fuel plates for this will result in failure to meet subsequent dimensional inspection requirements.

ALCO-NPE Specification No. FEI-34
Revision A - April 1, 1960

Title: Inspection of Brazed Fuel Assembly

Purpose: This specification covers the inspection of clean, brazed fuel assemblies (ALCO-NPE Specification No. FE-33). The fuel assemblies are visually and dimensionally inspected. Plate spacing inspection must be performed at this time.

Process: Visual Inspection - The brazed joints and the fuel plates are visually inspected for splatter, lateral spread of braze metal, pitting, and braze discontinuity.

1. A total of two inches (2 in.) of void in the braze joints of a fuel plate will be allowed. A void is defined as any area in which the braze metal is not at least flush with the inner surface of the side plates. The presence of voids in excess of the above amount is cause for rejection.
2. Braze runout on any fuel plate in excess of sixty-three thousandths of an inch (.063 in.) from the inner surface of the side plates is cause for rejection.
3. Braze metal splatter or pitting over the active core section is cause for rejection.
4. Any pitting or wash of the fuel plate caused by reaction with the braze metal in excess of one thousandth of an inch deep (.001 in.) is cause for rejection.

Dimensional Inspection - The brazed fuel assemblies are dimensionally inspected for squareness, width, water channel spacing, and sag or distortion of top and/or bottom plates. The data are recorded on an appropriate inspection form.

Plate spacings are measured longitudinally at the middle of the fuel plates at one ~~half~~ inch (~~1/2~~ in.) stations, beginning at the numbered end. Top and/or bottom fuel plate sag, or distortion is measured at corresponding stations by measuring the distance from the side plate edges to the surface of the fuel plates. Maximum allowable deviation is plus or minus ten per cent (+ 10%) of the nominal spacing. Deviations greater than the allowable are cause for rejection.

Air gauging to measure the spacings is not acceptable. A mechanical measuring device incorporating a calibrated elliptical probe has been used successfully. A steel ellipsoid, having one-tenth inch (0.100 in.) minor and one hundred fifty thousandths of an inch (0.150 in.) major axes, is mounted on the end of a one-tenth inch (0.100 in.) diameter tube approximately twenty-seven inches (27 in.) long. A one-inch thick plastic block, three (3) inches by six (6) inches, with a hole in the center allowing tube rotation, is mounted near the other end of the tube. A needle indicator is rigidly mounted on the tube, near the plastic block, parallel with the ellipsoid major axis. The needle is calibrated by rotating the ellipsoid between gauge blocks and the width of the space between gauge blocks marked on a piece of polar graph paper. The calibrations are fastened to the face of the plastic block.

The width of the assembly is measured with a three (3) inch micrometer at six locations along the top and bottom of the side plates for a total of twelve measurements per assembly. Measurements are taken at distances of one (1), six (6), eleven (11), sixteen (16), twenty-six (26) inches from the numbered end of the element. Failure to meet the specified width conditions is cause for rejection, unless specifically approved by the Contracting Agency or its authorized representative.

Equipment:

Water channel spacing probe and inspection equipment.

ALCO-NPE Specification No. FE-35

Title: - Machining of Brazed Fuel Assemblies to Length

Purpose: - This specification covers the machining to length of the cleaned and inspected brazed fuel assemblies (ALCO-NPE Specification No. FEI-34) prior to the attachment of the end boxes.

Process: - Two parallel vises are mounted on a vertical milling machine table with the faces of the vises parallel to the lengthwise table feed. The vises are spaced so that approximately one-half (1/2 in.) of the assembly will extend from the outer edge of each vise. The vise jaws are carefully tightened against the side plates. The fuel assembly ends are squared and cut to length using a four (4) inch long side cutting mill. The edges are carefully deburred with a file.

Equipment: - Vertical milling machine with table and travel that will accommodate the fuel element.

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ALCO-NPE Specification No. EBM-36

Title: End Box Castings

Purpose: This specification covers the stainless steel castings that will be machined and fitted to the fuel assemblies (ALCO-NPE Specification No. FE-35) to locate them in the grid plates of the reactor core, and direct the coolant flow along the fuel plates.

Material: The material to be used for casting end boxes is a .02 wt. % maximum cobalt content type 304-L stainless steel.

Process: Overall economic considerations may be a factor in the selection of the type of casting. Sand castings may require machining of the bore for locating purposes and hand polishing of the entire unmachined portion of the bore to obtain the required surface finish.

Inspection: The castings are visually inspected for surface imperfections such as blowholes, scabs, cold shuts, and/or entrapped sand. A surface finish of 125 RMS is required on all machined and internal surfaces.

The dimensional inspection will determine acceptability with respect to minimum dimensions required for cleanup and/or meeting requirements of the finished items.

Suppliers: Possible suppliers are:

Lebanon Steel Foundry
Lebanon, Penna.

Arwood Precision Castings Corp.
New York, N.Y.

ALCO-NPE Specification No. EB-38

Title: - End Box Machining

Purpose: - This specification covers the machining of the end boxes prior to attachment, by welding, to the fuel assemblies (ALCO-NPE Specification No. FE-35). The end boxes are attached to each end of the fuel assemblies to locate them in the grid plates of the reactor core, and to direct the coolant flow along the fuel plates.

Process: - The end box casting is mounted on a split or expanding mandrel after boring, if boring is required. The "solid" end of the mandrel is mounted on the milling machine table so that the end box is supported in the vertical position. The end box is positioned so that the wider dimension of the rectangular surfaces is parallel to the travel of the table. These surfaces are then straddle milled. For machining the other dimension of the rectangular surfaces, the end box is located by reference perpendicular to the previously machined surfaces. These surfaces are then straddle milled.

- This fixture is also used to locate and hold the end boxes during machining of the male end connections which are inserted into the brazed fuel assembly. An interference fit of two thousandths of an inch (0.002 in.) in both directions requires individual selection and machining of end boxes to each fuel assembly. These surfaces are side milled to provide the necessary fit and the end boxes are assigned to the appropriate brazed fuel assembly. Hand finishing of the unmachined inside surfaces may be required to obtain the required finish.

Equipment: - Milling machine.

ALCO-NPE Specification No. EBI-39

Title: Machined End Box Inspection

Purpose: This specification covers the visual and dimensional inspection of machined end boxes (ALCO-NPE Specification No. EB-38) prior to attachment to the fuel assembly (ALCO-NPE Specification No. FE-35).

Process: The machined castings are visually inspected for surface imperfections that have not cleaned up during machining. Any surface imperfection that results in an undersize dimension, when hand worked, is cause for rejection. The dimensional inspection will determine acceptability of the finished item per the appropriate drawing.

ALCO-NPE Specification No. FE-40

Title: Welding End Boxes to Fuel Element

Purpose: This specification covers the assembly, alignment and tungsten inert gas welding of end boxes (ALCO-NPE Specification No. EBI-39) to the fuel assembly (ALCO-NPE Specification No. FE-35).

Process:

The fit of the end boxes into the brazed assembly is adjusted so that a gap of one thirty-second of an inch ($1/32$ in.) is left between the ends of the side plates and the end box shoulders. Three-inch "C" clamps are placed across the middle of the side plates to hold the end boxes in place. The clamped assembly is placed on two parallel bars on a surface plate. The bottom inner surface of the end box base is zeroed on a dial indicator mounted on a surface gauge. The indicator is removed and the assembly is rotated one hundred eighty degrees (180°). The new bottom of the bore is indicated. Misalignment is corrected by tapping with a plastic hammer until the dial indicator readings are within one thousandth of one inch (0.001 in.). The fuel assembly is rotated ninety degrees (90°) and the above procedure repeated. The clamps are checked for tightness. The other end box is similarly adjusted. The position of each end box is checked by repeating the operations. The center lines of the end boxes are thus aligned with the centerline of the fuel assembly.

In welding the end boxes to the assembly, a rotatable jig is used to hold and position the assembly. The jig consists of a rotatable base plate to which the fuel assembly is strapped two inches from the ends of the brazed assembly. A ring is also attached at each end of the base plate through which four locating thumb screws are extended. The assembly is clamped to the base plate and the four thumb screws are carefully tightened to contact the end boxes. The "C" clamps remain in place during the welding operation.

The fuel assemblies are butt welded to the end boxes using a tungsten inert-gas process with argon gas and type ~~308~~ ³⁰⁷ bare filler wire. Only the side plates are welded to the end boxes, using the following procedures:

ALCO-NPE Specification No. FE-40 (Cont'd.)

A tack is made at the center of one side plate joint; another tack is made at the center of the other side plate joint; the first joint is welded over the full length and the second joint is then welded; the welds are made flush with the side plates; and the second end box is then welded in the identical manner.

Equipment:

T.I.G. welding equipment, rotatable jig and clamps.

ALCO-NPE Specification No. FE-41

Title: Final Machining of Fuel Element and Accessory Installation

Purpose: This specification covers the final machining of the fuel element (ALCO-NPE Specification No. FE-40) end boxes so that the centerline of the active fuel portion coincides with the centerline of the locating surfaces of the end boxes for proper positioning in the bottom grid plate and the top cover of the core. The fuel elements are also machined to final length if required. Holes are drilled for the pin and spring that are added to complete the fuel element.

Process: The fuel element is placed in a lathe with the inlet end box at the headstock. A standard expanding mandrel is inserted into the center bore of each end box and expanded. The mandrels are supported in the lathe between two four-jaw chucks. The element is located in the chucks so that the jaws move perpendicularly to the sides of the fuel element. This permits shifting of the element in any of four directions for proper alignment.

The element is centered with its centerline coinciding with the lathe centerline. This is done by first indicating the outside surface of the top fuel plate with a dial indicator mounted on a surface gauge placed on the lathe bed. The element is then rotated one hundred eighty degrees (180°), and the outside surface of the bottom fuel plate is indicated. If zero readings are not obtained for both top and bottom fuel plates, the element is shifted by adjusting the jaws of the chuck until both surfaces are zeroed in. The element is rotated ninety degrees (90°), and the procedure is repeated on the side plates of the fuel element. The centering is rechecked and corrected, if necessary.

The round portion of the inlet end box in the headstock is then machined to five one thousandths of an inch (0.005 in.) greater than the finished dimensions. The element is again rechecked for alignment, and the round portion is machined to finish size. After final machining of the inlet end box, the fuel element is reversed in the lathe so that the outlet end box is positioned at the headstock. The above procedure is then repeated for machining the outlet end box.

ALCO-NPE Specification No. FE-41 (Cont'd.)

Caution - Make cut only at the headstock end of the fuel element. The fuel element can be permanently distorted if a cut is made while driving through the length of the fuel element.

The fuel element is removed from the lathe, and the mandrels slipped from each end box. The fuel element is then placed in two parallel precision vises mounted on a vertical milling machine table. The vises are located to engage the rectangular section of the end boxes with the fuel element centerline parallel to the lengthwise feed of the milling machine. The overall length of the fuel element is measured with a thirty-six inch (36 in.) vernier caliper. If necessary, the ends of the end box are faced off with a four inch (4 in.) side mill cutter to the finished fuel element length.

Where required, the end boxes or supports are finish machined according to drawing. Attachments, where required, are made at this time. The fuel element shall be vised or gripped at the non-fuel bearing end boxes or supports to avoid distorting or damaging the fuel element.

The fuel element number is transferred to the flat plate surface of both end boxes. One-half inch (1/2 in.) metal stamps are used.

Equipment:

-
Lathe
Milling machine
Drill press

ALCO-NPE Specification No. FEI-42

Title: Final Inspection of Completed Fuel Element

Purpose: This specification covers the dimensional inspection of completed fuel elements (ALCO-NPE Specification No. FE-41). The fuel element is subsequently cleaned, checked for surface contamination and packaged for shipment.

Process: The final inspection consists of the following:

1. An inspection ring is placed around each end box. Both rings are made with identical outside diameters (3-1/2 in.) while the inside diameters are made to the maximum permissible diameter of the end boxes at the grid location areas. The rings are positioned on the end boxes and are placed in a pair of matching "V" blocks set on a surface plate. Concentricity is measured with a dial indicator at points corresponding to the nominal active core ends of the outside fuel plates at the centerline, while revolving the rings and fuel element through one hundred eighty degrees (180°). Maximum variations allowable is two thousandths of an inch (0.002 in.) total indicator run-out.
2. The perpendicularity of the shoulder, on the end box at inlet of the fuel element, must be checked with respect to the longitudinal axis of the fuel element. With the fuel element positioned in the matching "V" blocks, the base of a die-maker's square is laid on the surface plate and the arm is brought in contact with the shoulder. A feeler gauge is used to measure the variation. Maximum variation allowable is two thousandths of an inch (0.002 in.).
3. The length between the shoulders of the end boxes is measured with a thirty-six inch (36 in.) vernier caliper. The nominal over-all fuel element length is also measured in this manner. The tolerance for the measurements is plus or minus ten thousandths of an inch (0.010 in.).
4. Gross distortion of the completed fuel elements is checked by passing the element through a go-no-go box approximately ten per cent (10%) longer than the fuel element, with inside dimensions specified in the fuel element drawing. The fuel element must pass freely through this box for acceptance.

ALCO-NPE Specification No. FE-43

Title:

Preparation of Fuel Elements for Shipment

Purpose:

This specification covers the chemical cleaning, checking for contamination, and packaging for shipment of the finished fuel elements (ALCO-NPE Specification No. FEI-42).

Process:

If it is necessary to clean the surfaces of the fuel elements prior to shipment, the cleaning operation should be conducted in an area removed from the fuel fabrication plant and relatively free from airborne activity due to fissionable material. All units are to be pickled in warm ten per cent (10%) nitric acid (HNO_3) - water (H_2O) solution for ten minutes (10 min.), rinsed in hot running water and dried. Immediately after drying, the fuel elements are checked by the Health Physics Department for cleanliness and, if acceptable, each is wrapped in a heavy dry paper and inclosed in a plastic sheath which must be thermally sealed to protect the contents from the atmosphere. The components are then packaged in suitable shipping containers which are designed to protect the units against damage or contamination during storage and shipment.

POWDER METALLURGY CORE ORDER FORM

Core Order # _____

Order Date _____

No. of Cores Ordered _____

Order Completed _____

Uranium Dioxide Specifications per core:

1. Identification _____
2. Enrichment _____
3. Weight per cent _____
4. Grams per core _____
5. Particle size range _____

Boron Carbide Specifications per core:

1. Identification _____
2. Weight per cent _____
3. Grams per core _____
4. Particle size range _____

Stainless Steel Specifications per core:

1. Identification _____
2. Weight per cent _____
3. Grams per core _____
4. Particle size range _____

Theoretical Total Core Weight, grams _____

Desired Core Size: _____

Special Instructions: _____

POWDER METALLURGY CORE ORDER FORM

Data for Core Order # .

Deviations from the specified core composition or fabrication procedure:

Record of individual core weight and thickness: (To be completed unless otherwise specified.)

Average Core Weight _____

Average Core Thickness _____

No deviations from the specified core composition or fabrication procedure are to be made without the prior approval of _____

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POWDER METALLURGY CORE ORDER FORM

Data for Core Order # _____

A. Blending Operation

1. Total weight of core components to be batch blended for _____ cores.

a. Uranium dioxide: _____ grams.

b. Boron carbide: _____ grams.

c. Stainless steel: _____ grams.

2. Identification of blending container: _____

3. Blending device to be used: _____

4. Initial dry blending time: _____

5. Type of alcohol to be added: _____; volume to add: _____

6. Method of alcohol addition: _____

7. Alcohol to be added: _____

8. Final reblending time: _____

B. Cold Pressing Operation

1. Pressure to be used: _____

C. Sintering Operation

1. Sinter for _____ hours at _____ °F.

D. Coining Operation

1. Pressure to be used: _____

E. Other Operations

POWDER-MET FABRICATION FORM

Shipment Number _____ Jar Numbers _____ Type Material _____ Total Wt Material _____ Type Cores _____

Core Composition

Matrix _____ per core _____ grid

Poison _____ per core _____ gms

Fuel _____ per case _____ gns

Total Materials per Core _____ gm.

Original Weight % Fuel

NON-FUEL FABRICATION LOSS

Total Batch Weight After Pressing (B)

Total Hatch Weight After Sizing (G)

Non-Fuel Weight Loss (Difference) _____ gm

Total Fuel Injected into Cylinders _____ gm

Corrected Weight Percent in Extracted Camera

$$\frac{\Sigma \text{ Fuel}}{\Sigma A - \Sigma B - C} \times 100 = \text{Car Wt \% U}$$

INSPECTION RECORD

PLATE DATA						PLATE SPACING, MILS								
Plate Length	No. Plates	U ²³⁵ Per Plate			Total U ²³⁵	Space No.	Location, Inches				Inches From End	WIDTH		
							2½	9	15½	22		Top	Middle	Bottom
Long						1-2					1			
Short						2-3					6			
			Total Per Assembly			3-4					11			
Distance From Top of Side Plate to Fuel Plate						4-5					16			
Dist. From Front	2½	9	15½	22	5-6						21			
Top					6-7						26			
Bottom					7-8									
Core Order						Plate No.								
						1								
						2								
						3								
						4								
						5								
						6								
						7								
						8								
						9	10							
						10	11							
						11	12							
						12	13							
						13	14							
						14	15							
						15	16							
						16	17							
						17	18							
						Lean								

Plate Spacing _____ Mils ± _____

Longitudinal Bow: _____

Visual Inspection Record

Defect	No	Yes	Reject
Braze Metal Splatter			
Braze Metal Pitting			
Excessive Braze Flow			

Inspected By _____

Remarks:

FUEL UNIT FABRICATION RECORD

Type Unit _____ Destination _____ Shipped _____ On Tr. No. _____ Fuel Unit Number _____

Per Errata: "Chart will have to be redesigned to meet specification requirements!"

RADIOGRAPHIC INSPECTION SHEET OF FUEL PLATES

ASSEMBLY RECORD CARD

Jig Number-----

Inside Diameter of Jig Measured with an Inside Micrometer---

Width of Shim Plate #1 (As Coated)-----

Width of Shim Plate #2 (As Coated)-----

Width of Fuel Plate-----

Material Left Behind Side Plate Groove (Randomly Checked)---

Space Remaining in Jig

Inside Dimensions of Jig-----

Maximum Metal Remaining Behind Groove-----

Thickness of Shim Plates-----

Calculated Clearance-----

Theoretical Width of Assembly-----

Maximum Actual Brazed Width-----

Maximum Lean of Assembly-----

SLC 782

VIII SAMPLE CALCULATIONS

The fuel, burnable poison, and matrix powders are specified in terms of grams of uranium -235, boron-10, and stainless steel. Since the fuel is used in the form of UO_2 and the burnable poison in the form of natural B_4C , it is necessary to determine by calculation the quantities of these materials which are to be incorporated into each core. Each batch of as-received UO_2 is assayed for total uranium content as well as for isotopic concentration of uranium-235. Likewise, the concentration of boron and boron-10 in the boron carbide is accurately determined.

Sample calculations illustrating the method utilized in determining the required quantities of UO_2 and B_4C in each fuel plate are listed below.

A. Data required: (Values are for illustration purposes only)

Wt. % U-235 in U	93.07
Wt. % U in UO_2	87.63
Wt. % B-10 in B (natural)	18.09
Wt. % B in B_4C	75.9
gms. U-235 per plate	28.62
gms. B-10 per plate	0.02581

B. Determination of grams of UO_2 per plate:

$$\text{Grams of } \text{UO}_2 = \frac{28.62 \text{ (gm. U-235)}}{87.63 \text{ (wt. % U in } \text{UO}_2) \times 93.07 \text{ (wt. % U-235 in U)} \times \text{efficiency of add'n}^*} = 35.09$$

$$\text{Grams of coated } \text{UO}_2 = (\text{Grams of } \text{UO}_2) \times \frac{(\text{Batch wt. of } \text{UO}_2 + \text{coating wt.}) \text{ gms.}}{(\text{Batch wt. of } \text{UO}_2) \text{ gms.}}$$

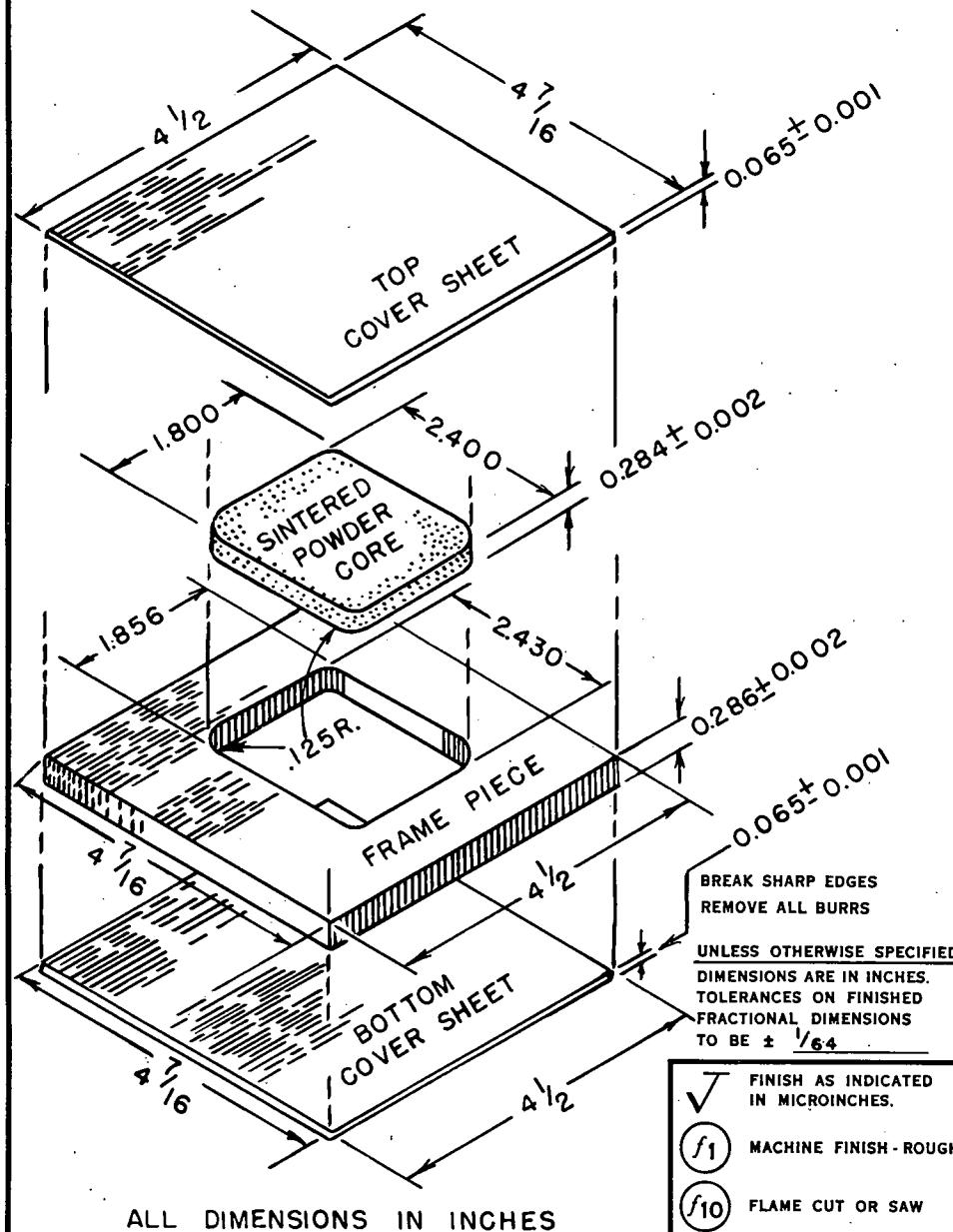
C. Determination of grams of B_4C per plate.

$$\text{Grams of } \text{B}_4\text{C} = \frac{0.02581 \text{ (gm. B-10)}}{75.9 \text{ (wt. % B in } \text{B}_4\text{C}) \times 18.09 \text{ (wt. % B-10 in } \text{B}_n) \times \text{efficiency of add'n}^*} = 0.188$$

As might be expected, the final density or the densification factor ($\frac{\text{Measured volume}}{\text{Theoretical volume}}$) of the fabricated core material has a significant effect on the charge of stainless steel powder required to meet dimensional specifications in the finished composite plate.

* Efficiency of additions depends upon plant, equipment, and personnel variables. It shall be determined by the manufacturer.

PART NO. [REDACTED]



DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.

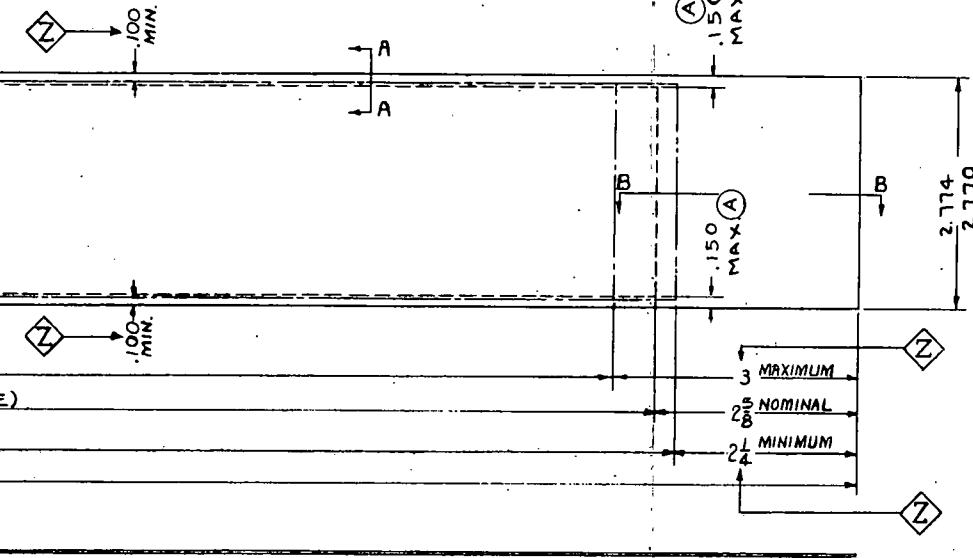
ALCO		ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N. Y., U. S. A.			
SCALE	REF.	DR.			
MATERIAL SPEC.		TR.			
		CHK.			
		APPR.			
		APPR.			
		MET.			
NAME					
EXPLDED VIEW OF TYPICAL FUEL PLATE. PRIOR TO HOT ROLLING.					
PART NO.					
AES 342					

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DATE	REV. RECORD	AUTH.	DR.	CHK.
12-9-59	A	DIM. 150 WAS .136	EB	
		PER 8861		

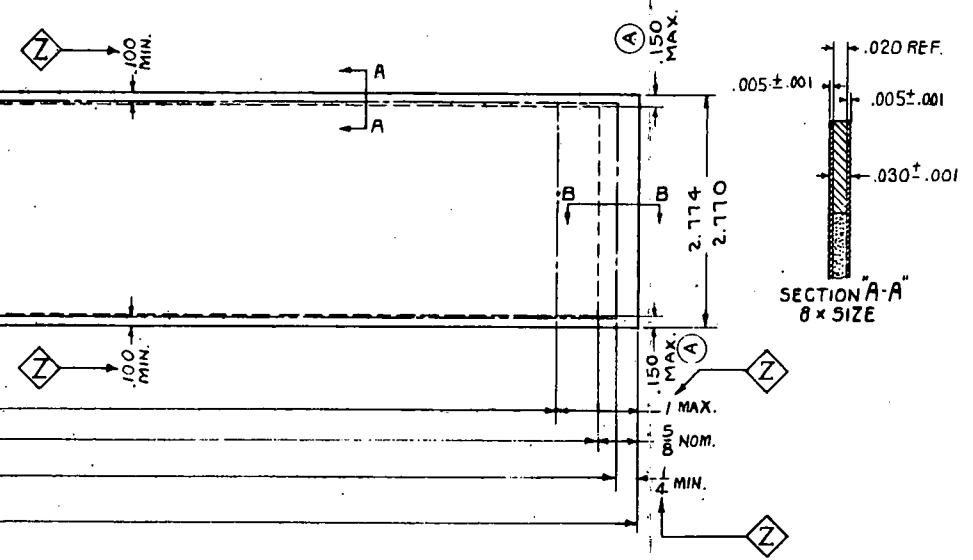
PART NO D9-13-2156

SECTION "B-B"
8 x SIZE



PART NO D9-13-2156-1

SECTION "A-A"
8 x SIZE



NOTE:-

ACTIVE CORE MUST FALL WITHIN
DIMENSIONS MARKED

PART NO	NAME
	FUEL PLATE-SIDE
	FUELPLATE

PART NO D9-13-2156

ALCO	ALCO PRODUCTS, INC.
	ATOMIC ENERGY DEPT.
	SCHEECTADY, N.Y. U.S.A.
SCALE	1/4" = 1'-0"
FULL SIZE	14-13-2015
MATERIAL SPEC.	TR. 7-10-59
CLAD-SS, TYPE 304L	CHL. 7-14-59
LOW COBALT	APPN. 7-14-59
FRAME-SS, TYPE 304L	APPN. 7-14-59
LOW COBALT	CORE AS SPECIFIED
NAME	NAME
FUEL PLATES (STATIONARY)	
PART NO.	D9-13-2156

UNLESS OTHERWISE SPECIFIED
DEVIATIONS AND TOLERANCES
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE 2

FINISH AS INDICATED
OR MICROSCOPIC
 MACHINED FINISH - ROUGH
 PLANE CUT OR SAW

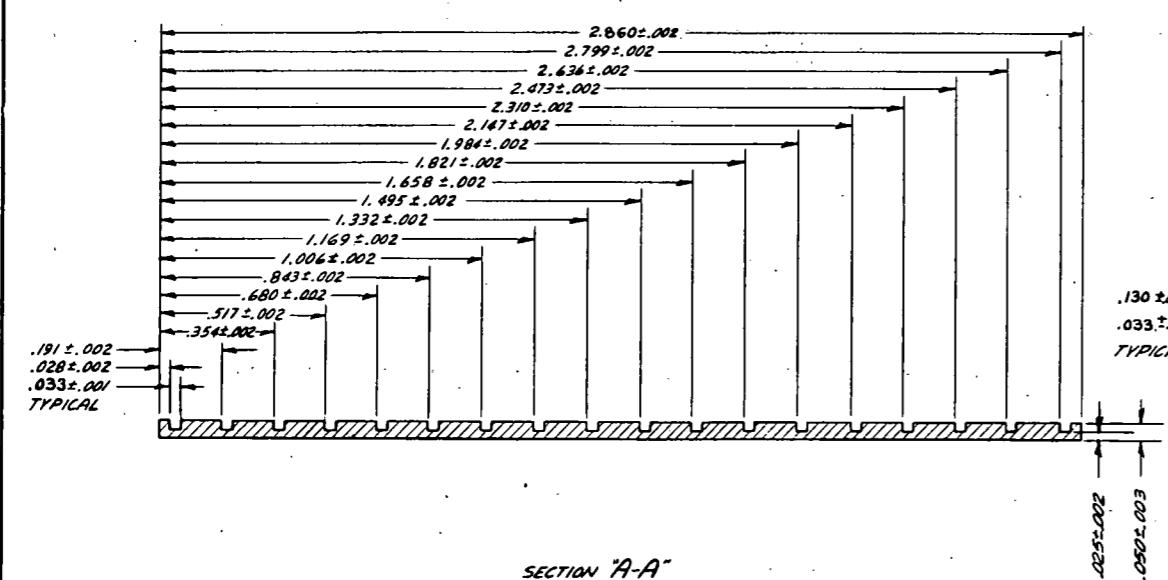
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SIDE PLATE 09-13-215

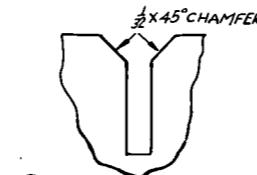
DATE	LET.	REVISION RECORD	AUTH.	DR.	CH.
12/17/59	A	VIEW 8' ADDED 0062	12/17/59	144	KA

27

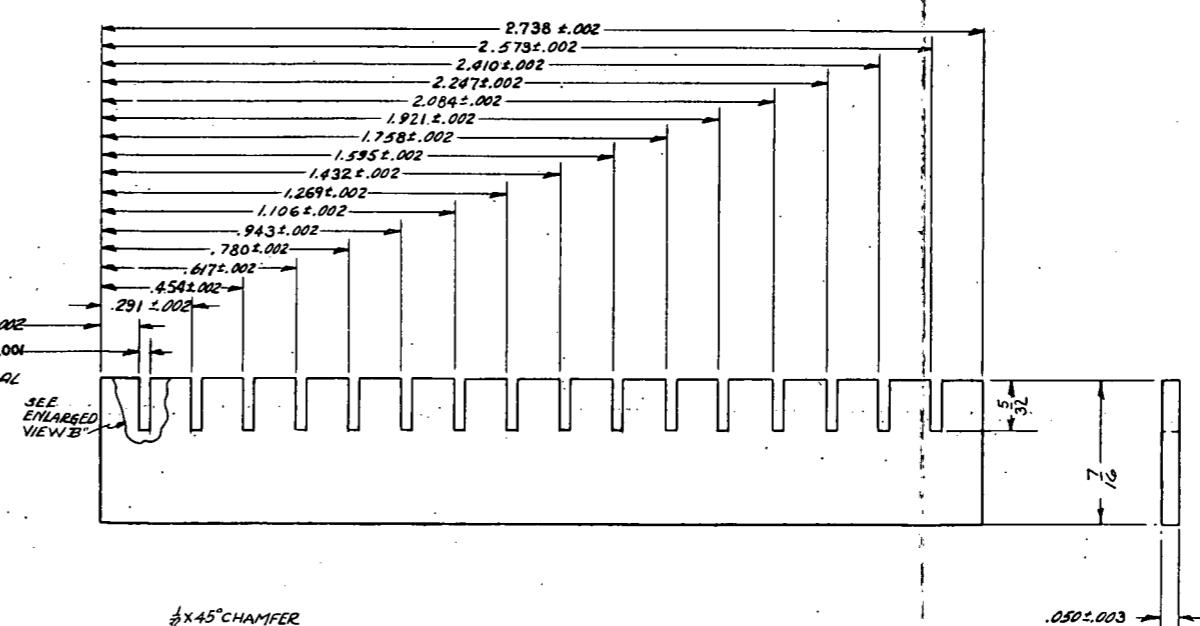
COMB. D9-13-2154-1



SECTION "A-A"
SCALE 4X SIZE
MATERIAL: STAINLESS STEEL TYPE-304L, LOW COBAL



(A) VIEW "B"
TYPICAL FOR ALL SLOTS
SCALE 10X SIZE



COMB
SCALE 4 X SIZE
MATERIAL: STAINLESS STEEL TYPE-308L LOW COBALT

PART NAME	PART NO.
SIDE PLATE	09-13-2154
COMB	08-13-2154-1

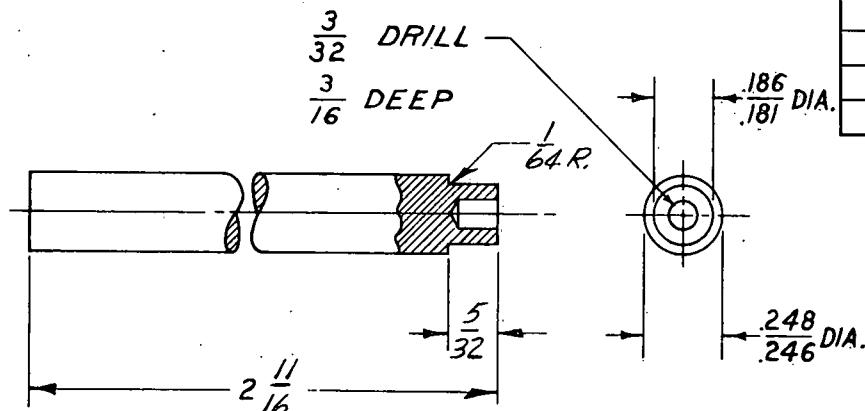
ALCO		ALCO PRODUCTS, INC.			
		ATOMIC ENERGY DEPT.			
		SCHENECTADY, N. Y., U. S. A.			
SCALE MATERIAL SPEC. SEE NOTES.	FULL	29-13-2075	DR.	Jenrich	6-29-59
			TR.		
			CHP.	Electrical	7/6/59
			APPR.	T. P. 2000	7-3-55
			APPR.		
			MET.	ECE	7-3-59
NAME SIDE PLATE (FUEL ELEMENT STATIONARY)					
PART NO.					
D 9-13-2154					

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PART NO

A9-13-2024



NOTES:

125 ✓ ALL OVER.
BREAK SHARP EDGES.

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE $\pm 1/64$.

✓ FINISH AS INDICATED
IN MICROINCHES.

f1 MACHINE FINISH - ROUGH

f10 FLAME CUT OR SAW

