SEP 4 1962

Copy No 19

MASTER

APAE Memo-311
Revision 1

AEC Research and
Development Report
UC-81, Reactors - Power
[Special Distribution]

specifications and fabrication
procedures for type 3 fuel elements

Contract No. AT[30-1]-2639
with U. S. Atomic Energy Commission
New York Operations Office

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPARTMENT

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

APAE Memo-311
Rev. 1
AEC Research and
Development Report
UC-81, Reactors, Power
(Special Distribution)

SPECIFICATIONS AND FABRICATION PROCEDURES
FOR TYPE 3 FUEL ELEMENTS

By:
E. C. Edgar
H. R. Clayton

Approved By:
M. H. Dixon, Project Engineer

Issued: April 27, 1962

Contract No. AT(30-1)-2639
with U.S. Atomic Energy Commission
New York Operations Office

ALCO PRODUCTS, INC.
Nuclear Power Engineering Department
Post Office Box 414
Schenectady 1, N.Y.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

AEC LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights: or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

ALCO LEGAL NOTICE

This report was prepared by Alco Products, Incorporated in the course of work under, or in connection with, Contract No. AT(30-1)-2639, issued by U.S. Atomic Energy Commission, New York Operations Office and subject only to the rights of the United States, under the provisions of this contract, Alco Products, Incorporated makes no warranty or representation, express or implied, and shall have no liability with respect to this report or any of its contents or with respect to the use thereof or with respect to whether any such use will infringe the rights of others.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

DISTRIBUTION

External
Copies

- 1 - 2 New York Operations Office
 U.S. Atomic Energy Commission
 376 Hudson Street
 New York 14, New York

 Attention: I.M. Adler
- 3 New York Operations Office
 U.S. Atomic Energy Commission
 376 Hudson Street
 New York 14, New York

 Attention: Library
- 4 - 6 U.S. Atomic Energy Commission
 Washington 25, D.C.

 Attention: Chief, Water Systems Project
 Branch (Army Reactors)
 Division of Reactor Development
 Mail Station F-311
- 7 U.S. Atomic Energy Commission
 Washington 25, D.C.

 Attention: Chief, Evaluation and Planning Branch
 Civilian Reactors
 Division of Reactor Development
 Mail Station F-311
- 8 U.S. Atomic Energy Commission
 Chief, New York Patent Group
 Brookhaven National Laboratory
 Upton, New York

 Attention: Harman Potter
- 9 Idaho Nuclear Power Field Office
 U.S. Army Engineer Reactors Group
 P.O. Box 2108
 Idaho Falls, Idaho

DISTRIBUTION (CONT'D)

External
Copies

10 U.S. Atomic Energy Commission
Reports and Statistics Branch
Division of Reactor Development
Washington 25, D.C.

11 - 12 Office of the Chief of Engineers
Dept. of the Army
Building T-7
Washington 25, D.C.

Attention: Chief, Projects Branch
Nuclear Power Division

13 - 15 Nuclear Power Field Office
U.S. Army Engineer Reactors Group
Fort Belvoir, Virginia

Attention: Chief, Nuclear Power
Field Office

16 Nuclear Power Field Office
U.S. Army Engineer Reactors Group
Fort Belvoir, Virginia

Attention: O.I.C. SM-1

17 Chief, U.S. Army Reactors Group
Fort Greely, Alaska
APO 733
Seattle, Washington

Attention: O.I.C. SM-1A

18 Commanding Officer
U.S. Army Polar Research
and Development Center
Fort Belvoir, Virginia

Attention: Nuclear Power Officer

DISTRIBUTION (CONT'D)

External
Copies

19 - 21 Office of Technical Information Extension
 P.O. Box 62
 Oak Ridge, Tennessee

22 Union Carbide Nuclear Corporation
 Oak Ridge National Laboratory
 Y-12 Building 9704-1
 P.O. Box "Y"
 Oak Ridge, Tennessee

 Attention: L.D. Schaffer

23 Alco Products, Inc.
 Post Office Box 145
 Fort Belvoir, Virginia

 Attention: W.C. Best

24 - 73 New York Operations Office
 U.S. Atomic Energy Commission
 376 Hudson Street
 New York 14, N.Y.

 Attention: Ira M. Adler, Project Engineer

Internal
Copies

74	K. Kasschau	83	R.A. Shaw
75	J.G. Gallagher	84	E.C. Edgar
76	J.F. Haines	85	A.S. Wilder
77	G.E. Humphries	86	E.G. Moote
78	M.H. Dixon	87	J.R. Coombe
79	J.P. Tully	88	J.M. Ravets
80	N.F. Taylor	89 - 90	Critical Facility File
81	H.R. Clayton	91 - 92	Metallurgy Group File
82	R.W. Kelleman	93 - 100	NPED File

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

TABLE OF CONTENTS

	<u>Page</u>
I. SCOPE -----	1
II. QUALITY ASSURANCE PROVISIONS -----	3
A. Qualification of Plate Fabrication Procedure -----	3
1. Preparation of Qualification Samples -----	3
2. Tests for Qualification -----	3
a. Visual Inspection -----	3
b. X-Ray Examination -----	4
c. Homogeneity -----	4
d. Bond Integrity -----	4
e. Clad-Core-Clad Thickness -----	4
f. Total Plate Loading -----	5
g. End Conditions -----	5
h. Fragmentation or Stringering -----	5
i. Qualification of Europium Master Suppressor Compacts -----	5
B. Qualification of Fuel Assembly Welding Procedure -----	5
1. Fabrication of Fuel Assembly -----	5
2. Qualification Tests -----	8
a. Dimensional and Visual Inspection -----	8
b. Weld Joint Examination -----	8
C. Manufacturing Procedure -----	8
1. General -----	8
2. Identification of Components -----	8
3. Production Samples -----	9
4. Cleanliness -----	9
III. PROCESS AND MATERIAL SPECIFICATIONS -----	11
ALCO-NPE Specification No.FM-1 -----	13
ALCO-NPE Specification No.FM-50 -----	15
ALCO-NPE Specification No.CM-14-A -----	17
ALCO-NPE Specification No.FM-51 -----	21
ALCO-NPE Specification No.EBM-36 -----	23
ALCO-NPE Specification No.FP-4A -----	25
ALCO-NPE Specification No.FP-52 -----	27

TABLE OF CONTENTS (CONT'D)

	<u>Page</u>
ALCO-NPE Specification No.FP-53 - - - - -	29
ALCO-NPE Specification No.FP-54 - - - - -	31
ALCO-NPE Specification No.FCI-9 - - - - -	33
ALCO-NPE Specification No.FC-55 - - - - -	35
ALCO-NPE Specification No.FC-56 - - - - -	37
ALCO-NPE Specification No.FCI-57 - - - - -	39
ALCO-NPE Specification No.S-5 - - - - -	41
ALCO-NPE Specification No.SFP-58 - - - - -	51
ALCO-NPE Specification No.SFP-59 - - - - -	55
ALCO-NPE Specification No.FP-22 - - - - -	57
ALCO-NPE Specification No.FP-23 - - - - -	59
ALCO-NPE Specification No.C-24 - - - - -	61
ALCO-NPE Specification No.FP-25 - - - - -	63
ALCO-NPE Specification No.SP-26A - - - - -	65
ALCO-NPE Specification No.C-18 - - - - -	67
ALCO-NPE Specification No.FP-26 - - - - -	69
ALCO-NPE Specification No.FPI-27 - - - - -	71
ALCO-NPE Specification No.FP-60 - - - - -	73
ALCO-NPE Specification No.FPI-29 - - - - -	75
ALCO-NPE Specification No.I-48 - - - - -	77
ALCO-NPE Specification No.FPI-30 - - - - -	79
ALCO-NPE Specification No.FP-6 - - - - -	81
ALCO-NPE Specification No.EB-38 - - - - -	83
ALCO-NPE Specification No.EBI-39 - - - - -	85
ALCO-NPE Specification No.WFE-61 - - - - -	87
ALCO-NPE Specification No.FEI-1 - - - - -	101
ALCO-NPE Specification No.WFE-62 - - - - -	103
ALCO-NPE Specification No.FE-40 - - - - -	105
ALCO-NPE Specification No.FE-41 - - - - -	107
ALCO-NPE Specification No.FEI-42 - - - - -	109
ALCO-NPE Specification No.FE-43 - - - - -	111
ALCO-NPE Specification No.FEI-43 - - - - -	113
ALCO-NPE Specification No.A-45 - - - - -	119
ALCO-NPE Specification No.A-46 - - - - -	121
ALCO-NPE Specification No.FEI-47 - - - - -	123
IV. PACKAGING AND PACKING FOR SHIPMENT - - - - -	125
V. SAMPLE CALCULATIONS - - - - -	127
VI. DRAWINGS - - - - -	129

LIST OF FIGURES*

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1	Fuel Element Fabricated by Reference Method Section Parallel to Rolling Direction. Optimum Core Structure	6
2	Suppressor Section of a Roll Clad SM-2 Fuel Plate	7
3	As-Sintered Fuel-Element Cores Containing 26 w/o UO_2 - 1.0 w/o ZrB_2 in a Prealloyed Type 347 Matrix after Sintering 2 Hours at 2150°F in Vacuo	40
4	SM Type 3 Core Stationary Fuel Plate Pack Configuration (AES 590)	53
5	SM Type 3 Core Control Rod Fuel Plate Pack Configuration (AES 591)	54
6	Welding Fixture with Stationary Element Assembled	92
7	Power Source and Weld Sequence Timer	95
8	Automatic Welding Head Mounted on Side Beam Carriage	96
9	Spacer Removal Unit	97
10	Fuel Plate Spacing Gauge	98
11	Welding Fixture with Top Side Plate Removed to Show Position of Spacers	99
12	Weld Sequence Pattern (entire fuel plate welded)	100

Drawing No.

A9-13-2183	Spacer	93
A9-13-2184	Shim	94

* List of drawings appear in Section VI.

SPECIFICATIONS AND FABRICATION PROCEDURES
FOR TYPE 3 FUEL ELEMENTS

I. SCOPE

The specification contains both process and product requirements to be met by the Fabricator. The ability to produce the required end product can only be demonstrated through destructive testing of qualification components manufactured under fabrication procedures identical to the procedures to be utilized in the production of the core loading components.

The procedures contained herein describe in detail the process developed at Oak Ridge National Laboratory, Battelle Memorial Institute, and Alco Products, Incorporated for manufacturing this component.

Differences in equipment and other factors existing at other plants may necessitate modification of some of the procedures to arrive at the same result. For this reason, complete qualification of the Fabricator's process is required. This qualification of the Fabricator's process constitutes an integral part of this specification and the production of the desired component.

The fuel elements herein specified consist of thin plates of a dispersion of highly enriched UO_2 and ZrB_2 in a stainless steel matrix which is clad with stainless steel on all surfaces. These fuel plates are welded to side plates to form a rectangular section approximately square in cross section, considered a fuel assembly. End adapters are attached by welding to form a fuel element.

II. QUALITY ASSURANCE PROVISIONS

Quality control of the fuel elements is primarily attained by rigid adherence to 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.

A. Qualification of Plate Fabrication Procedure

Qualification shall be performed by subjecting sixteen sample stationary and sixteen sample control rod fuel plates as prepared in Part 1 (Preparation of Qualification Samples) to the tests outlined in Part 2 (Tests for Qualification) of this section. The Fabricator shall not proceed with fabrication of the fuel plates required in the end product until it has been demonstrated to the satisfaction of the Commission that requirements of Section 2a - 2i (Tests for Qualification) described below, have been met.

Upon Commission approval for the production of the enriched fuel plates, the Fabricator shall manufacture fifty-four (54) enriched stationary fuel plates. These plates shall be checked for reactivity in a critical facility. Upon Commission approval, the Fabricator shall then continue with the production of enriched fuel plates.

1. Preparation of Qualification Samples

The sixteen sample fuel plates shall be prepared in conformance with the exact and complete materials and fabrication procedure which is used in the manufacture of the fuel elements, and in accordance with dimensions specified. 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 chemical analysis of qualification plates shall be performed only by a laboratory which has satisfactorily demonstrated its ability to analyze for uranium, europium and boron content of stainless steel dispersion type fuel plates. Choice of a laboratory for chemical analysis work shall be approved by the Commission.

2. Tests for Qualification

a. Visual Inspection

The sixteen 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 sixteen sample fuel plates shall meet all dimensional requirements and shall not exhibit any oxide indentations or pits over one thousandth an inch (0.001 in.) deep, scratches over one thousandth of an inch (0.001 in.) deep, dents over the core area, blisters, scale or surface discoloration.

b. X-Ray Examination

The sixteen sample fuel plates shall then be X-rayed to delineate the core area and to reveal any segregation and voids or other internal defects. The radiographs shall be made using proper techniques with a fine-grained film such as Eastman "M", or equivalent. The film shall be exposed and processed to yield a gamma density of 1.15-1.35 over the core area. The radiographs shall be used as the basis of measurements of core length and width, inactive edges and ends.

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

c. Homogeneity

If the sixteen sample fuel plates exhibit satisfactory homogeneity as evidenced by examination of the X-ray films, four of the sixteen shall be further examined. Five miniature samples of full-plate thickness approximately one inch square shall be sheared from each of the four 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. The five samples from each of two of the above fuel plates shall be dissolved in their entirety and chemically analyzed for uranium. Ten samples from the remaining two fuel plates shall be dissolved in their entirety and chemically analyzed for boron content. The results shall be expressed in weight percent (wt %) of the specimen in each of the twenty samples above.

For each of the two plates, the uranium requirement is that the content of each sample expressed in weight percent (wt %) shall be within plus or minus two percent ($\pm 2\%$) of the tested plate average. The boron requirement is that the content of each sample expressed in weight percent (wt %) shall be within plus or minus ten percent ($\pm 10\%$) of the tested plate average.

d. 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 sixteen sample fuel plates. After proper preparation and etching, the samples shall show no evidence of lack of bond at the following interfaces; clad to core, core to frame, clad to frame, suppressor to core, suppressor to frame and suppressor to clad, upon metallographic examination at 100 diameters.

e. Clad-Core-Clad Thickness

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

f. Total Plate Loading

Eight sample fuel plates shall be completely dissolved and analyzed. Four of the eight fuel plates shall be analyzed for total uranium and europium content. The remaining four fuel plates shall be analyzed for total 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	+ 0.75% - 1.0%
Boron	$\pm$ 5%
Europium	$\pm$ 5%

g. End Conditions

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

h. Fragmentation and Stringering

One longitudinal sample at least one-half inch (1/2 in.) long shall be taken from the active and suppressant 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 Figures 1 and 2 respectively. The europium oxide shall exhibit no evidence of reaction with the suppressor matrix material at magnifications up to 1500 diameters.

i. Qualification of Europium Master Suppressor Compacts

Two sample master compacts prepared in accordance with ALCO-NPE Specification No. S-5 shall be sectioned into three one-quarter inch (1/4 in.) strips taken from the middle and each end of the compacts. The average europium content of the six samples, expressed in weight percent (wt %), must be within plus or Minus two-tenths of one weight percent ($\pm$ 0.2 wt %) of the required concentration.

B. Qualification of Fuel Assembly Welding Procedure

Qualification shall be performed by subjecting one welded stationary fuel assembly and one control rod fuel assembly as prepared in Part 1 (Fabrication of Qualification Sample) to the tests outlined in Part 2 (Qualification Tests) of this section. The Fabricator shall not proceed with fabrication of the fuel assemblies required in the end product until it has been demonstrated to the satisfaction of the Commission that requirements of section 2a and 2b (Qualification Tests) described below have been met.

1. Fabrication of Fuel Assembly

Procedure qualification shall be performed by fabricating a dummy stationary fuel assembly and a dummy control rod fuel assembly. Type 347 low cobalt, low

100X

Glyceria Regia

69036

Figure 1. Fuel Element Fabricated by Reference Method Section
Parallel to Rolling Direction. Optimum Core Structure

500X

N-69328

100X

N-69

Figure 2. Suppressor Section of a Roll Clad SM-2 Fuel Plate

tantalum stainless steel of the same heat and condition as used in the production fuel elements shall be used in the dummy fuel assemblies. The fuel plates shall be fabricated from solid stainless steel.

2. Qualification Tests

a. Dimensional and Visual Inspection

The qualification test assemblies shall meet all requirements contained in this specification.

b. Weld Joint Examination

Transverse sections through rows of welds #2, 8 and 14 (see Figure 12) shall all be examined at diameters up to 100 X for weld penetrations and soundness. All welds shall exhibit penetration into the fuel plate of a minimum of ten thousandths of an inch (0.010 in.) and a maximum of thirty thousandths of an inch (0.030 in.) and shall be free from inclusions, voids, cracks or other injurious defects.

Longitudinal sections of two welds each from rows #5, 9 and 13 (see Figure 12) shall be microscopically examined at magnifications up to 100 diameters for weld penetration and soundness. All welds shall exhibit penetration into the fuel plate a minimum of ten thousandths of an inch (0.010 in.) and a maximum of thirty thousandths of an inch (0.030 in.) and shall be free from inclusions, voids, cracks, micro-fissures or other defects. Length of fuel plate-side plate fusion shall be one-half inch (1/2 in.) minimum and five-eighths inch (5/8 in.) maximum.

C. Manufacturing Procedures

1. General

The fuel element component is designed for radioactive service in pressurized water and once placed in operation cannot be subjected to maintenance or repair. It is imperative, therefore, that only the highest degree of quality obtainable, with respect to materials of construction, equipment and workmanship be incorporated into the finished product.

2. Identification of Components

Positive identification of each fuel plate and fuel element must be maintained during fabrication of the fuel elements. In addition to the identification numbers placed on the fuel plates and fuel elements, a symbol indicative of the manufacturer shall be placed on the end fixture of the stationary element and on the handle end of the side plate of the control rod element.*

* As shown on the applicable drawing

3. Production Sample

After the production of each twenty enriched fuel elements and after the completion of production, a dummy fuel assembly shall be fabricated and tested as outlined in Section II-b.

4. Cleanliness

All component parts and fixtures shall be hand cleaned with acetone, technical, FED. O-A-51, prior to assembly. Cleanliness is to be maintained throughout fabrication by keeping the assembly covered with clean paper or polyethylene film during the time that no work is being performed. Workmen handling the fixtures, component parts or finished elements shall wear clean, white cotton gloves to prevent contamination by dirt, oil, grease, fingerprints or other foreign matter.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

III. PROCESS AND MATERIAL SPECIFICATIONS

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Material: - Uranium Dioxide Powder

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

Analysis: - UO_2 with a minimum of 87.6 wt % uranium.
- U-235 isotopic enrichment 93 ± 1.0 wt %.

Specifications: - Particle Size: 75 to 149 microns

Spheroidicity:

95% spheroidal particles, with smooth surfaces, as determined (per batch) by microscopic examination of three slides of one hundred particles each. Spheroidal particle major to minor axis ratio shall not exceed 2 to 1.

Impurity Level:

B-1 ppm max

Be-0.5 ppm max

Li-5 ppm max

Co-10 ppm max

Cd-10 ppm max

Gd-10 ppm max

Al-200 ppm max

No other metallic impurity to exceed 100 ppm with total not to exceed 500 ppm.

Lattice Constant: 5.4700 - 5.4708 angstroms

Phase:

X-ray diffraction shall not detect any phase other than UO_2 . Inclusions or grain boundary phases shall not exceed 20% by volume as determined by petrographic analysis.

Petrography:

Minimum of 80% of structure by volume shall be cubic UO_2 phase.

Grain Size:

Average grain size shall be less than 15 microns in diameter and the maximum grain size shall not exceed 40 microns.

Density:

Density as determined by xylene pycnometer shall not be less than 10.52 grams per cubic centimeter.

Internal Porosity:

Internal porosity as determined by petrographic techniques is not to exceed 4% by volume. The procedure for determining internal porosity by petrographic techniques is given at end of this specification.

DETERMINATION OF INTERNAL POROSITY
BY PETROGRAPHIC TECHNIQUES

As-received UO_2 shot is crushed lightly in an agate mortar to obtain particles of about 20 to 40 microns in average diameter. These particles are mounted on a glass slide in a fused sulfur-selenium mount having an index of refraction of 2.35_{Li}. The volume percent of pores is measured at 800 to 1000X magnification by any standard quantitative procedure such as superimposing a grid over the microstructure and counting the number of intersections that touch a pore. The volume fraction of pores is then equal to the number of pores touching grid intersections divided by the total number of grid intersections. The grid spacing should be such that the total number of intersections is approximately equal to the number of pores. Porosity should be measured in fifty particles approximately 20 microns in diameter to obtain the average value.

Material: - Zirconium Diboride Powder

Purpose: - This specification covers ZrB_2 powder for use as burnable poison in the core of stainless steel, dispersion type fuel plates. The desired particle size is not available commercially. Therefore, this specification describes both the starting material and the method of consolidation.

Analysis of Starting Material:

Boron (Total)	- 19.1 ± 0.1 wt %
Carbon	- 0.1 wt % maximum
Iron	- 0.3 wt % maximum
Hafnium	- 1.0 wt % maximum
Zirconium	- 79.0 wt % minimum
B-10 isotopic concentrations	- 18.5 ± 1.5 wt %

Consolidation Procedure:

- a. Compact approximately 25 grams of ZrB_2 at 30 tsi (do not use a binder).
- b. Arc melt in an argon atmosphere using a water cooled, copper crucible and tungsten electrode. Use a maximum of two passes so as to reduce possibility of tungsten pickup. The specifications should not be construed as to require melting of 25 gram buttons in an arc furnace. If, for example, a skull melting furnace is available it should be possible to melt the entire core loading at one time.
- c. Leach in a 50-50 nitric acid-water solution to remove any copper or surface oxides.
- d. Crush button or skull in a steel mortar to pass a 100 mesh screen.
- e. Separate the -100 + 200 mesh fraction for use.
- f. Thoroughly blend all powder required for the core loading and analyze for boron content.

Composition After Consolidation Operation:

Boron	- 18.9 ± 0.2 wt %
Carbon	- 0.1 wt % maximum
Iron	- 0.3 wt % maximum
Hafnium	- 1.0 wt % maximum
Tungsten	- 1.0 wt % maximum
Copper	- 0.02 wt % maximum
Zirconium	- 78.0 wt % minimum

Supplier: - U.S. Borax and Chemical Corp. or equivalent.

- Title: - Cladding Material - Type 347 Low Cobalt, Low Tantalum Stainless Steel
- Purpose: - This specification covers the material used for cladding, frames, combs, side plates and end fixtures.
- 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 the 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 maximum and tantalum shall be 0.01 maximum.

Chemical Composition: in weight percent

<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 plus 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 two percent and a maximum of ten percent.

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

<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 two to ten percent (2-10%) 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 two percent (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 this welding test shall be as mutually agreed upon between the Supplier and Fabricator. 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 one inch 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 (15-5¹²). 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 one inch thick sheet bar shall not be any greater than that specified in the Inclusion Chart of ASTM E-45-51 specification.

Mechanical Properties:

	<u>Tensile Strength</u>	<u>0.2% Offset Yield Strength</u>	<u>% Elongation in 2 In.</u>
Plate, Sheet and Strip	75,000 psi	30,000 psi	40%

Purchase Conditions:

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

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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Material: - Prealloyed Type 347 Stainless Steel Powder
- Purpose: - This specification covers stainless steel powder for use as matrix material in dispersion type fuel elements for nuclear reactor cores.
- Composition: - This stainless steel powder shall meet the following chemical analysis.

<u>Element</u>	<u>Specification</u>	<u>Aim</u>
Carbon	0.05 wt % max	0.02 wt %
Nickel	9 to 10 wt %	10 wt %
Chromium	17 to 19 wt %	18 wt %
Silicon	1.0 to 1.25 wt %	
Phosphorous	0.010 wt % max	
Sulphur	0.010 wt % max	
Columbium	10X carbon min; 1.00 wt % max	
Manganese	0.40 wt % max	
Cobalt	0.025 wt % max	
Tantalum	0.010 wt % max	
Oxygen	0.60 wt % max	

- Particle Size: - The powder shall be 325-mesh size, with all material passing through a 325-mesh size screen.

- Particle Shape: - Irregular.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - End Box Castings

Purpose: - This specification covers the stainless steel castings that will be machined and fitted to the fuel assemblies to locate them in the grid plates of the reactor core, and direct the coolant flow along the fuel plates.

Materials: - The material to be used for casting end boxes is a two hundredths weight percent (.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 shall be 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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title:

- Coating of UO_2 Powder Prior to Blending

Purpose:

- This specification covers the process of coating UO_2 particles with camphor so that segregation will not occur during blending and handling.

Process:

- Before the UO_2 can be used for blending, the individual particles must be coated with camphor in order to prevent segregation of the UO_2 in the fuel core. To achieve this coating, the following procedure is used. Batches of approximately 400 grams of UO_2 are screened through a 100-mesh screen and retained on a 200-mesh screen. The exact amount is set by criticality limitations. The screening is easily accomplished by hand. The UO_2 is weighed to an accuracy of plus or minus three hundredths percent ($\pm 0.03\%$) and placed in a large porcelain evaporating dish.

A mixture of camphor and alcohol is prepared by dissolving a one-half ounce (1/2 oz) block of USP-grade refined camphor in 600 ml of absolute methanol. The solution should be made directly before use and not stored. Otherwise, alcohol will evaporate and a higher concentration of camphor will be present.

The camphor-methanol mixture is poured into the evaporating dish to a depth such that the UO_2 is completely covered. After standing approximately one minute, the excess liquid is poured off and the wet UO_2 is left in a hood under slightly negative pressure for 24 hours. The coated UO_2 is then screened to a -100 +200-mesh, weighed, the amount of camphor pickup recorded and then stored in capped jars for use in preparing fuel cores. The amount of camphor pickup should not exceed one thousandth of one gram (0.001) per gram of UO_2 and should be subtracted from the weight of the powder used to give the correct weight of UO_2 .

Equipment:

- Balance with capacity of 500 grams with accuracy of 10 milligrams, cover, pan, and 100 to 200-mesh US standard screens.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Weighing of Component Powders

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

Zirconium Diboride
Stainless Steel
Uranium Dioxide

Process: - The component powders for each individual core are separately weighed and combined in a single blending jar (container may be substituted for jar wherever it is used). 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. ZrB_2 is the first material loaded into the blending jar and is followed by the stainless steel, and finally the UO_2 . This sequence permits the diboride 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 Zirconium Diboride

The burnable poison in the form of ZrB_2 is weighed to an accuracy of at least three-tenths of one percent (0.3%). A sheet of glazed paper with glazed side up and of known weight is placed on the pan. The ZrB_2 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 ZrB_2 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 ZrB_2 . The powder is weighed to a tolerance of one hundredth of one percent (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. Prior to weighing, a correction factor for each batch of UO₂ coated in ALCO-NPE Specification No. FP-4A will be calculated and used to determine the amount of coated UO₂ required to meet the UO₂ requirements for each compact.

$$\text{Correct Factor} = \frac{\text{weight of coated UO}_2}{\text{weight of UO}_2 \text{ prior to coating}}$$

$$\text{Coated UO}_2 \text{ required per compact} =$$

$$\frac{\text{UO}_2 \text{ req per compact} \times \text{Correction Factor}}{\text{Efficiency of additions}^*}$$

A weighing accuracy of three one-hundredths of one percent (0.03%) is required. After weighing, UO₂ is added to the jar containing the ZrB₂ 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.

* The efficiency of additions is dependent on equipment, plant and personnel variables. It should be determined by the Fabricator for his particular operation.

Title: - Blending Fuel Powders

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

Process: - In the past either of two types of blenders have been successfully used. The first was a modified U.S. Stoneware Company Double Cone Blender, Model 733. The double cone blender is modified by replacing the cones with a pair of two-quart steel cans mounted with the vertical axis of the cans at a thirty degree (30°) angle with the vertical. The second was a standard ball mill roller drive on which was placed a two-quart can mounted within a circular band or pipe about twelve inches in diameter. The two quart can was mounted with its vertical axis at an angle of 30° to the vertical and this gave the same blending action as the modified cone blender. The cans are rotated at about eighty revolutions per minute (80 rpm).

The blending jars containing the fuel, poison and matrix materials are placed into the two-quart cans, with adequate packing to prevent breakage and to keep the jars in a vertical position in relationship to the vertical axis of the cans, and blended dry for one hour. The jars are then removed from the blending cans and one cubic centimeter (1 cc) of camphor-methanol solution, as prepared in ALCO-NPE Specification No. FP-4A, is added. The jars are then closed and sealed with masking tape and reblended for two additional hours. The blended powders are then ready for the first pressing operation. The identity of the contents of the blended fuel cores must be maintained at all times.

This operation should be done in an area in which the minimum room temperature is sixty-five degrees fahrenheit (65°F).

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Compacting Fuel Powders

Purpose: - This specification covers the compacting of fuel, poison and matrix material powders into a "green" compact. This is the initial fabrication operation in producing, by powder metallurgy, a fuel core for a fuel plate. The "green" compact will be approximately ten percent (10%) greater in thickness than the finished dimension required for fuel plate billet assembly.

Process: - The blended powders are placed in the die cavity of a rectangular shaped female die having top and bottom movable male inserts. Hydraulic pressure is applied to the die inserts, compacting the powders to a pressure of 50 tons per square inch (50 tsi). The following are the die sizes and pressures used in the "green" pressing operation.

<u>Type Die</u>	<u>Die Size</u>	<u>Pressure</u>
Stationary	2.625 in. x 2.941 in.	385 tons
Control	2.375 in. x 2.941 in.	350 tons

Because of the radioactive material (the uranium dioxide fuel) it is necessary to perform this operation in a negative pressure dry box. The pressing sequence is as follows:

1. Lubricate die cavity lightly with a solution of one-half ounce (1/2 oz) of camphor dissolved in fifty milliliters of absolute methanol. The die insert faces may occasionally be lubricated if the core sticks to the die on ejection.
2. Lower bottom punch to give enough space for powder charge.
3. Transfer fuel core from blending jar to die cavity with as little motion as possible.
4. Level powder in die cavity with a scoopula, brushing any powder on top of female die into die cavity (vibration methods cannot be used as they tend to segregate fuel mixture).
5. After powder charge is level in die cavity the bottom punch is lowered and the top punch is inserted.

6. Pressure is applied to punches, fifty tons per square inch (50 tsi), and held for fifteen seconds (15 sec) and released.
7. The top punch is removed and the green compact is ejected from the die cavity.

The compacts have good green strength, and should not present any difficulty in handling. However, the compacts should be sintered soon after pressing since they lose some of the binder after an extended period of time and tend to crumble at the corners upon handling. Green density should be seventy-five to seventy-seven percent (75 to 77%) of theoretical (approx. 6.36 to 6.54 g/cc).

Green compacts should be checked periodically for dimensions.

Compact identity shall be maintained throughout subsequent pressing.

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

- Title: - Weighing of Fuel Compacts after Cold Pressing
- Purpose: - This specification covers the weighing of "green" compacts 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 two hundred and fifty grams (250 g) capacity and accuracy of ten milligrams (10 mg) and glovebox.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: - Sintering of Compacts (+ Binder Removal)
- Purpose: - This specification covers the sintering of "green" compacts of dispersions for use in fuel plates. The compacts consist of UO_2 and ZrB_2 dispersed in a matrix of stainless steel.
- Process: - Binder Removal: The camphor-alcohol binder may be removed in a separate operation or during the sintering operation. The choice of the procedure depends only upon selection of the most expedient means. Regardless of whether the binder is removed before sintering or during sintering, the compacts must be placed and supported in the tray or box to be used in the sintering furnace. After binder removal, the compacts are friable and cannot be handled or transferred individually. For binder removal a furnace with a capacity of producing a vacuum of one (1) micron of mercury pressure at a temperature of one-thousand degrees fahrenheit (1000°F) is required.

The compacts should be placed in the furnace in such a manner that warping or sticking will not occur during the sintering operation. Molybdenum foil can be used to separate the compacts. The number of compacts which can be handled is dependent upon the size of the uniform heat zone and criticality requirements. Before heating, the system should be pumped to a low pressure and checked for any possible leaks. The temperature is then raised slowly until degassing is completed. The pressure should not exceed fifty (50) microns during degassing, and heating should be delayed if the pressure exceed fifty (50) microns. The compacts are heated to one-thousand degrees fahrenheit plus or minus twenty-five ($1000^\circ\text{F} \pm 25$) and held until ten (10) microns Hg is attained. Specimens are then furnace cooled in vacuum.

- Sintering: - The sintering operation as described below includes the removal of the binder. If the binder is removed prior to sintering, the heating rate is controlled by the necessity to maintain a uniform hot zone and a low vacuum. It should be noted that if a vacuum system with a low pumping capacity is used, some outgassing of the stainless powder will be detected in the range eighteen hundred to two thousand degrees fahrenheit (1800 - 2000°F). If this outgassing occurs, the heating is stopped until a vacuum of at least five (5) microns is attained. A vacuum furnace capable of operating at twenty-two hundred degrees fahrenheit (2200°F) with a pressure of the order of one tenth (0.1) micron Hg pressure with a leak rate less than

twenty-five (25) microns Hg pressure per hour from a one (1) micron pressure, is required for sintering. It cannot be emphasized too strongly that a vacuum is required in order to prevent oxidation and subsequent loss of boron. Inert gas or hydrogen atmosphere is unsatisfactory.

The compacts should be placed in the furnace in such a manner that warping or sticking will not occur. Molybdenum foil can be used to separate the compacts. Before heating, the system should be pumped to a low pressure and checked for any possible leaks. The temperature is then raised slowly until degassing is completed. The pressure should not exceed five (5) microns during degassing and heating should be delayed if the pressure exceeds five (5) microns. The temperature is raised to twenty-one hundred and fifty degrees fahrenheit plus or minus twenty-five ($2150^{\circ}\text{F} \pm 25$) after degassing has been completed and held at less than one (1) micron Hg pressure for two hours after which power is turned off and the compacts are cooled in the furnace under a vacuum. The heating rates are controlled so that a uniform temperature is maintained as indicated by three thermocouples, two of which are near the heating element, and one of which is in the center of the hot zone.

- Title: - Coining of Fuel Compacts after Sintering
- Purpose: - This specification covers the coining of sintered fuel compacts of fuel dispersion for use in fuel plates.
- Process: - The same die as used for green pressing may be used for coining. Compacts are coined at fifty tons per square inch (50 tsi). The pressure is held for fifteen seconds (15 sec).

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Final Inspection and Storage of Fuel Compacts

Purpose: - This specification covers the final inspection of fuel compacts of fuel dispersion for use in fuel plates.

Process: - The finished compacts shall be visually and dimensionally inspected. Obvious flaws, or surface imperfections, due to nicks, cracks, spalling or breaking are cause for rejection.

Weight loss should not exceed one gram (1 g) from the original weight. Typical microstructures of sintered and coined compacts are shown in Figure 3. It should be noted that the structures appear to be relatively dense and that no reaction of the ZrB_2 is detectable. The finished compacts shall be wrapped in paper in batches and stored in a dessicator. If the storage period is more than forty-eight hours, a vacuum dessicator shall be used.

Equipment: - Micrometers
Low Power Magnifier
Dessicator and Vacuum Dessicator
Balance

250X

As Polished

N61772

500X

Electrolytic NaCN Etch

N61771

Figure 3. As-Sintered Fuel-Element Cores Containing 26 w/o UO_2 - 1.0 w/o ZrB_2 in a Prealloyed Type 347 Matrix after Sintering 2 Hours at 2150°F in Vacuo

Title: - Europium Bearing Flux Suppressor Core

Note: All dimensions and weights used in this specification are based on the use of an existing die and a particular suppressor design (size and europium oxide content). The dimensions and component weight percent (wt %) ratios shall be adjusted to meet the requirements of the suppressor design being used.

Purpose: - This specification covers the materials and process for preparing the europium flux suppressor core. The flux suppressor, a small europium-bearing segment, forms a part of the fuel plate core at one end of the composite fuel plate. The integral suppressor serves the function of minimizing flux peaking.

Process: - The flux suppressant, europium oxide, is dispersed in a matrix of elemental powders. The iron, nickel and chromium elemental powders are mixed to provide a matrix of the following composition:

Hydrogen annealed Electrolytic
Iron (99.0% min) - 71 wt %
Electrolytic Chromium - 18 wt %
Carbonyl Process Nickel
(99.5% min) - 11 wt %

Maximum Impurities

	<u>Iron</u>	<u>Nickel</u>	<u>Chromium</u>
Oxygen	0.300 w/o	0.200 w/o	0.100 w/o
Carbon	0.020	0.100	0.020
Cobalt	0.020	0.020	0.020
Silicon	0.030	0.030	0.030

Flux Suppressor Core Preparation:

1. General

The neutron absorbing material shall be a high-purity europium oxide containing a minimum of ninety-eight weight percent (98 wt %) europium oxide. The silicon content shall not exceed two hundred parts per million (200 ppm).

(1) Preparation of Europium Oxide from the Oxalate Condition:

The material must be prepared by:

- (a) "Calcining" at 950°C in air, resulting in a cubic crystal structure, or
- (b) "Conditioning" at 1650°C in air, resulting in a monoclinic crystal structure.

Note 1 - Intermediate temperature treatments in preparation of the oxide other than either (a) or (b) above, are not permitted.

Note 2 - Subsequent mixing of "calcined" and "conditioned"(cubic and monoclinic) materials is not permitted.

Composition:

Each batch of oxide shall be analyzed for europium oxide. Each batch should contain a minimum of ninety-eight percent (98 %) europium oxide.

Thoria:

The thoria content will be determined by alpha activity measurements. Alpha activity shall not exceed ten disintegrations per minute per milligram of sample above background. (This is equivalent to five counts per minute per milligram above background on a detector with a fifty percent (50%) alpha counting efficiency). The detector shall be an internal proportional counter and shall be calibrated with a known alpha source which has been previously standardized by the National Bureau of Standards or other approved agency. The sample shall not weigh more than fifty milligrams (50 mg), and shall be distributed evenly on a one inch (1 in.) diameter stainless steel planchett.

Note: The above alpha activity limits should be adequate for careful out-of-glove box handling. It is recommended however, that sufficient air samples be taken under local operating conditions by the Fabricator's Health Physics personnel to insure against unsafe airborne contamination.

Particle Size:

The particle size should not be greater than fifteen (15) microns.

(2) Pressing

Prior to high firing, the powder is pressed into small cylindrical pellets to facilitate powder handling. Approximately 35 grams of the material, measured by a ten cubic centimeter stainless steel beaker is pressed into an individual pellet. The measured amount of oxide is poured into the cavity of a double acting, eight tenths of an inch (0.8 in.) diameter powder metallurgy die, leveled and pressed into pellet form by applying a pressure of about thirty-three tons per square inch. The resulting pellets are of sufficient strength for handling and have dimensions of eight tenths of an inch (0.8 in.) in diameter by eight tenths of an inch (0.8 in.) length.

(3) High Firing

Approximately ten pellets weighing between 300 - 350 grams comprise the firing batch size. The individual pellets are placed in a tungsten crucible approximately 2 x 2 x 7 inches in size which is constructed by edge-welding one-eighth inch (1/8 in.) sheet stock. The loaded tungsten crucible is inserted in a reactor grade graphite crucible mounted in the center of an induction coil. Amorphous thermatomic carbon powder is packed between the reactor grade graphite crucible and the outer quartz furnace tube to serve as an insulator. A reactor grade graphite block with an attached off-grassing stem is placed over the reactor grade graphite crucible to prevent the thermatomic graphite from contaminating the europium oxide pellets. The remainder of the quartz tube is then filled with amorphous thermatomic carbon powder and finally capped with a gas-tight, brass end plug. A hydrogen gas stem is attached to the lid to permit passage of hydrogen to the pellets during the firing operation. The exit hydrogen gas escapes through the stem attached to the top of the graphite crucible. The pellet firing is carried out at three thousand and ninety plus or minus twenty-five degrees fahrenheit ($3090 \pm 25^{\circ}\text{F}$) for a period of three hours. The hydrogen atmosphere gas is dried hydrogen gas with a dewpoint of at least minus sixty degrees fahrenheit (-60°F). The power is varied initially to control the rate of temperature rise in

the furnace; a rate of 570°F/hr is average. Temperature measurements are made on the surface of the pellets by sighting an optical pyrometer through the off-gassing stem. Upon completion of the firing, the power is shut off and the furnace cooled to approximately 300°F, at which time it is disassembled and the fired pellets removed.

(4) Crushing

The fired pellets are crushed to a -325-mesh size by a method which will not produce excessive fines, using a series of intermediate screening operations. Initially one-third of the fired batch size is crushed using only impact-type strokes. Circular grinding motions were found to produce considerable fines in the crushed oxide. After the pellets have been initially broken down, the product is placed in a series of vibrating screens which separate out the 100,-100,+270,-270,+325, and -325-mesh fractions. Each fraction is then recrushed until the entire material is of a -325-mesh size. The various sizing separations are necessary to minimize presence of fines. The final product from each batch is examined microscopically to determine if the particles are irregular and not rounded. Since the percentage of europium generally varies in high firing, a representative sample of each batch of high-fired oxide is analyzed by wet chemistry for total europium content expressed in weight percent.

Finished requirements are:

- (a) Maximum particle size is forty-four (44) microns
- (b) Continuous stringers of europium oxide fines in finished absorber plates, made in strict accordance with specified fabrication procedures, which are the direct result of excessive fines in the starting material, are not permitted.
- (c) Europium shall be eighty-five to eighty-eight weight percent (85 to 88 wt %).

(5) Tests

(a) Weight Change

A specimen from each processed lot or batch of europium oxide shall be tested for weight change by firing in a dry hydrogen (dew-point at least -60°F) atmosphere for one and one-half hours at twenty-two thousand and fifty plus or minus 25 degrees fahrenheit ($2250 \pm 25^{\circ}\text{F}$). The specimen shall be cold pressed in a one-quarter inch diameter die at a pressure of thirty-three tons per square inch (33 tsi) before firing. The pellet is fired on a molybdenum lined-type 316 stainless steel boat in a leak-tight inconel muffle. Any weight gain or weight loss in excess of eight thousandths of a gram (0.008 gms) will be cause for rejection of the lot or batch of europium oxide which this specimen represents. The specimen shall weigh one and five tenths plus or minus fifty thousands of a gram ($1.5 \pm .05$ grams) before firing.

(b) Sample compacts shall be made from each batch of high-fired material. Microscopic examination at magnification up to fifteen hundred diameters (1500) shall indicate no undesirable reaction of any type and all of the chromium shall be in solution.

(6) Handling

After high firing, the europium oxide must be shipped, stored and handled under conditions which preclude the pickup of moisture.

2. Manufacture of the Dispersion of Europium Oxide in Stainless Steel

The inserted flux-suppressor portion of the core is a section obtained from the sintered and coined compact containing europium oxide homogeneously dispersed in austenitic stainless steel.

(1) Calculations

The flux suppressors and matrix powders are specified in terms of europium and stainless steel. Since the europium is in the

form of europium oxide, it is necessary to determine by calculation the quantities of these materials which are to be incorporated in each core. Each batch of europium oxide which is treated is analyzed for europium. After high-firing, the compound shall contain a minimum of eighty-five weight percent (85 wt %) europium. The stainless steel matrix is obtained by sintering the elemental iron, nickel and chromium powders. Sample calculations illustrating the determination of the quantities of materials required for one flux suppressor are attached in the appendix.

The following illustrates the techniques used for fabrication of master suppressor compacts. The fabrication techniques for both the stationary fuel plate suppressor and the control rod fuel plate suppressors are identical, the only differences are the pressing die sizes and the amounts of materials.

The materials necessary to fabricate one master suppressor compact for each of the two different sizes is listed below:

<u>Material</u>	<u>Stationary</u>	<u>Control Rod</u>
Europium oxide	13.67 gms	12.37 gms
Iron powder	26.93	24.41
Chromium powder	6.83	6.19
Nickel powder	4.17	3.78

(2) Weighing of Component Powders

The europium oxide, iron, chromium and nickel powders are separately weighed in quantities to provide one core. This material is placed into four ounce pyrex, wide mouthed, screw cap jars for the blending operation. The powders are weighed to an accuracy of plus or minus three tenths percent ($\pm 0.3\%$).

(3) Blending

The powders are blended in order to obtain a homogeneous mixture of the europium oxide and matrix material. A modified U.S. Stoneware Company Double Cone Blender, Model 733, has been used successfully, as has a converted standard ball mill. The double cone blender is modified by replacing the cones with a pair of two-quart steel cans mounted with the vertical axis of the cans at a thirty degree angle with the vertical.

The standard ball mill containers are replaced with two-quart steel cans mounted in a ring with the cans at a thirty degree angle with the vertical. This is placed on a ball mill and rotated at about ninety revolutions per minute. Both methods give an oblique blending motion. Up to ten blending jars are placed into each two-quart can with the vertical axis of the blending jars parallel to the vertical axis of the steel cans. Styrofoam or equivalent liners are made to separate and protect the blending jars. The cans are rotated at this oblique angle for three hours, after which the powder is ready for the first compacting operation.

(4) Initial Pressing Operation

The blended powders are cold pressed into a compact using the floating sleeve powder metallurgy dies used for compacting the fuel cores. The die sizes are as follows:

<u>Component</u>	<u>Width</u>	<u>Length</u>
Stationary fuel die	2.620 in.	2.941 in.
Control rod fuel die	2.370 in.	2.941 in.

Since no radioactive material is present, the operation may be done in a conventional manner, but as the press usually enclosed in a dry box the pressings are usually done on the same press as the fuel compacts. The powder from one blending jar is carefully transferred to the die cavity and levelled, the top section of the male die is inserted into the die body and the die is then raised until a pressure of ten tons per square inch (10 tsi) is reached. This pressure is held fifteen seconds after which the pressure is released, the die plunger removed and the green compact ejected from the die cavity.

Extreme care must be exercised in removing and transfer of the thin fragile green compacts to prevent corner breakage. To avoid unnecessary handling, the pressed compacts are removed from the die and placed directly on the sintering boat.

(5) Sintering of "Green" Compacts

The compacts are sintered in a conventional dry hydrogen atmosphere, sintering furnace equipped with a cooling chamber.

The green compacts are placed on a molybdenum screen placed in the bottom of a Type 316 stainless steel, sintering boat. The molybdenum screen prevents the possible reaction of the europium oxide with the silicon in the stainless steel. The boat of compacts is placed into the cool zone of the furnace and held until the hydrogen atmosphere dew point reaches -60°F or better. The boat is then moved into the hot zone ($2250^{\circ} \pm 25^{\circ}\text{F}$) for one hour after which the boat is returned to the cool zone to cool below 300°F . Then the boat is air cooled to room temperature.

(6) Repressing of Sintered Compacts

After cooling the compacts are repressed. After carefully loading a compact into the original die cavity the male portion of the die is inserted and the pressure is raised to thirty-three tons per square inch (33 tsi) the operation is completed as in operation (4).

(7) Resintering of Compressed Compacts

This operation is identical as that described in operation (5) above.

(8) Coining of Sintered Compacts

After careful loading into the original dies, the sintered compacts are coined at thirty-three tons per square inch (33 tsi) for fifteen seconds.

(9) Inspection

The compacts are inspected and if chips and flaws are observed, the compact is rejected. The compact is also rejected if the thickness measurement of sixty-four thousandths of an inch (0.064 in.) varies more than plus or minus two thousandths of an inch (± 0.002 in.)

(10) Machining

The individual suppressors are either milled on a precision milling machine, or sheared and ground to final size. The following are the final sizes necessary:

<u>Component</u>	<u>Width</u>	<u>Length</u>	<u>Thickness</u>
Stationary	$2.625 \pm .001$ in.	$0.064 \pm .002$ in.	$.250 \pm .002$ in.
Control	$2.375 \pm .001$ in.	$0.064 \pm .002$ in.	$.250 \pm .002$ in.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Fuel Plate Billet Assembly

Purpose: - This specification covers the fabrication, assembly, welding and evacuation operations entailed in the manufacture of fuel plate billets for hot rolling into fuel plates.

Process: - The fuel plate billet is composed of a picture frame, two cover plates, a fuel and a suppressor core and an evacuation stem attached to the picture frame to allow evacuation of the billet after final assembly and welding of the cover plates to the picture frame. The dimensions of the components are shown in Figures 4 and 5.

1. Component Fabrication

Frames and cover plates are machined to size from sheet or plate material purchased to ALCO-NPE Specification No.CM-14-A. All machined surfaces are finished to a maximum of one hundred and twenty-five rms (125). The evacuation stem is a twelve inch length of three-sixteen inch (3/16 in.) heavy wall Type 304 stainless steel tubing and is welded to the picture frame by means of T.I.G. welding. If a filler metal is required, a Type 308 stainless steel welding wire is permitted. In the event that equipment is available and it is desired to punch the hole in the picture frame, there is no objection as long as the dimensions can be met. If the frames are punched, care must be taken that no lip or depressed area is caused by punching that would cause later trouble in the assembly of the billets.

2. Cleaning, Assembly, Scaling and Evacuation

It is essential that billet components be clean and free from grease and oxide in order to assure sound metallurgical bonds between all clad and fuel components. An acceptable technique is as follows:

- a. Vapor degrease frames and cover plates.
- b. Scratch brush all mating surfaces of picture frame and cover plates with a power driven stainless steel brush. It is imperative that the stainless steel brush be kept clean.

- c. Rinse in a hot detergent solution at one hundred sixty to one hundred and eighty degrees fahrenheit (160 to 180°F). The detergent shall not contain any boron or halogen compound.
- d. Rinse in hot water one hundred sixty to one hundred eighty degrees fahrenheit (160 to 180°F) until all traces of detergent have been removed.
- e. Air dry quickly, a heated, clean air blast is often helpful to prevent water stains.
- f. The billets are assembled as shown in Figures 4 and 5 with the flux suppressor core at the end opposite the evacuation stem. The billets are clamped in a vise and welded. The weld is made by the T.I.G. process with a fillet weld encircling the point between each cover plate and the outside of the picture frame. These welds must be vacuum tight. Practical experience indicates that a double weld is desirable; however, single pass welds may be used if they are demonstrated to be vacuum tight and do not crack during hot rolling. It may be necessary to weld the billets in an inert gas dry box if excessive oxidation develops between the cover plate and picture frame interface, which will cause an area of non-bonding. This will appear as a blister on the fuel plate surface later in production. The welding of the evacuation stem to the picture frame is the last welding operation. A rough leak test is performed on the billets after the completion of welding by applying a pressure of fifteen psi to inside of the billet through the evacuation stem using either argon or helium gas (helium preferred) and testing all welds with a soap solution or a commercial leak testing solution. The evacuation is accomplished by attaching the evacuation stems to a vacuum system and evacuating to a pressure of less than one micron of mercury. The packs are heated to six hundred degrees fahrenheit (600°F) during the evacuation procedure to remove any volatiles or gasses before the stem is sealed by hot forging to produce a leak tight pack.

Figure 4. SM Type 3 Core Stationary Fuel Plate Pack Configuration (AES 590)

- Title: - Hot Rolling of Fuel Plates
- Purpose: - This specification covers the hot rolling of the fuel plate billets to obtain the clad and frame to core bond, and dimensionally prepare the resultant composite fuel plate for subsequent processing.
- Process: - Hot rolling. Packs are hot rolled from a hydrogen atmosphere muffle to reduce the formation of oxide scale. Without the use of hydrogen, scaling is so severe at twenty-two hundred degrees fahrenheit (2200°F) that only one or two passes can be made. The twenty-two hundred degrees fahrenheit (2200°F) rolling temperature has been found to produce the most desirable core structure. At lower temperatures the breakup and stringering of UO_2 is more pronounced and at higher temperatures excessive reaction of the ZrB_2 and subsequent boron loss occurs. Heating requires an inconel muffle with at least a thirty-six inch (36 in.) hot zone at twenty-two hundred degrees plus or minus twenty-five degrees fahrenheit $2200^\circ \pm 25^\circ\text{F}$. The muffle shall be leak tight. Hydrogen with a dew point of at least minus sixty degrees fahrenheit (-60°F) will be used as the atmosphere gas inside the muffle. A sufficient flow rate is maintained to prevent oxidation during heating and to promote reduction of any oxide scale formed during the rolling operation.

Billets are preheated fifteen minutes (15 min) before rolling and reheated decreasing times ranging from five to two minutes (5 to 2 min) as the plates become thinner. The hot rolling operation should be completed as quickly as possible and the number of plates handled at one time should be small enough that excessive reheat times will be avoided. The amount of boron lost will be dependent upon the time at temperature. A heavy initial reduction is used to insure densification of the core and to obtain bonding of the cladding to the core on the first pass. The first pass is made with the stem entering the mill last, which provides that the suppressor section enters the mill first. Plates are flipped and reversed between each pass. The rolls and muffle must be kept clear of loose oxide scale and care must be taken that oxide particles are not rolled into the plate surfaces.

A typical rolling schedule is as follows:

1. Preheat pack for fifteen minutes (15 min)
2. Reduce thirty percent (30%) - stem end last
3. Reheat five minutes (5 min)
4. Reduce thirty percent (30%)
5. Reheat three minutes (3 min)
6. Reduce twenty percent (20%)
7. Reheat two minutes (2 min)
8. Continue twenty percent (20%) reduction passes and two minutes (2 min) reheats until plates are fifty thousandths of an inch (0.050 in.) thick.
9. Anneal five minutes (5 min)
10. Air cool

After Step 10, plate numbers are stamped on the suppressor ends of the plates in the inactive area. This number will later be sheared off in processing and restamped in a permanent location in the inactive portion near the suppressor. After hot rolling and marking, approximately five inches (5 in.) may be sheared off each end to facilitate handling.

- Title: - Composite Plate Core Layout
- Purpose: - The hot rolled plates are fluorescoped 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 fluorescoped, 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.

1. 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 template indicates scribe lines one-half inch ($1/2$ in.) beyond the sides of the fuel core and three inches (3 in.) beyond the ends.

After cold rolling, the template locates scribe lines allowing a sheared plate width approximately eighty-five thousandths of an inch (.085 in.) wider than the final machined plate. The lengths are sheared to provide approximately one sixty-fourth of an inch ($1/64$ in.) excess inactive material to be removed in final machining.

2. 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 or equivalent 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.

Caution: Special care is exercised in identification to insure identifying the europium bearing end of the fuel plate.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- 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 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, indentations or weakening. Holddown unit pressures must be such that the cladding is not destroyed or weakened. Good house-keeping 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

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title:

- Pickling

Purpose:

- This specification covers the pickling of stainless steel 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 component plates after flatten annealing or brazing.

Process:

- The work is pickled in an aqueous solution of fifteen percent nitric acid and five percent hydrofluoric acid (15% HNO_3 , 5% HF) at 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. 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 plates.

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 lined tanks are recommended.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- 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 stringing 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, 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 housekeeping 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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: - Side Plate Grooving
- Purpose: - This specification covers the machining of grooves in stainless plates to be used as the side plates of the fuel element.
- Process: - Conventional machine shop practice for the machining of stainless steels may be used to groove the side plates per the applicable drawing. Special care must be 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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- 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:
1. All parts entering the degreaser shall be dry. Soft annealed material must be handled very carefully to avoid bending and distortion.
 2. Load parts onto racks in the condensing zone of the degreaser so that they do not touch each other, and in such a manner as to insure complete drainage of solvents.
 3. Lower or raise finished parts in the degreaser at a rate not to exceed twelve inches (12 in.) 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 line during spraying. Allow parts to remain in vapor until condensation ceases, three to five minutes (3 to 5 min). Parts shall be completely dry before removing from the degreaser. 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.

3. Solvent

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 (260°F) or boiling point of trichloroethylene exceeds one hundred ninety-five degrees fahrenheit (195°F).

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

Title:

- Final Machining of Fuel Plates or Side Plates

Purpose:

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

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title:

- Machined Fuel Plate Fluorescopic and Visual Inspection

Purpose:

- This specification covers the fluoroscopic inspection of the fuel plates to determine their acceptability with respect to core width, length, 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 go-no-go basis. The acceptability of the plate is determined with respect to core width, length, edge and end cladding width. Fuel plates that fail this inspection may be radiographed as a positive check on dimensions. Core length, width, width of edge and end cladding are measured directly from the X-ray film. Plates which do not meet dimensional requirements are rejected. Every tenth 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. The fuel plates shall not contain indentations, blisters or rolled-in scale. Scratches and pits shall not be deeper than one thousandth of an inch (0.001 in.).

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title:

- Annealing of Fuel Plates and Side Plates

Purpose:

- This specification covers the flatten annealing of cleaned, machined plates (stainless steel or stainless clad) to facilitate assembling into the proper array and to meet plate spacing dimensions in the fuel unit. The plates are stack annealed in a clamping jig.

Process:

- 1. Fuel Plates

After machining, the fuel plates are annealed to stress relieve, flatten and densify. One side of each plate is covered with a thin coat of a mixture of one part by volume of Fisher Precisionite levigated alumina or equivalent, ten parts by volume of water, and a few drops of a wetting agent such as Kodak Photo-flow, or equivalent. An even coating may be applied either by spraying or by painting with a three inch camels hair brush. The coated plates are dried about fifteen minutes (15 min) at two hundred and fifty degrees fahrenheit (250°F) in a standard drying oven. The plates are stacked in a flattening jig consisting of two-three quarter inch (3/4 in) thick stainless steel plates with holes spaced approximately four inches (4 in.) along each edge. All points of contact between the plates and jig are first covered with the same mixture used to separate the fuel plates.

The jig plates are bolted firmly together with three-eighths inch (3/8 in.) bolts. Tightening the bolts uniformly to twenty or thirty foot-pounds (20-30 ft lbs) with a torque wrench is desirable. A hydrogen furnace with a 6 x 8 x 30 inch zone capable of two thousand and fifty plus or minus twenty-five degrees fahrenheit (2050 ± 25°F) is required. A dry hydrogen atmosphere (-80°F dewpoint at the inlet) is required to keep the plates bright. In annealing, the jig is placed in the hot zone at below four hundred degrees fahrenheit (400°F) then brought up to two thousand and fifty degrees fahrenheit (2050°F) and held for one hour. The plates are furnace cooled to below four hundred degrees fahrenheit (400°F), pulled into the furnace cold zone, or removed from the furnace and cooled to room temperature.

After removal from the furnace, the plates are scrubbed under flowing water to remove the alumina. Care should be taken to avoid distortion or scratching of the plates. The annealed steel is soft and can be easily scratched.

2. Side Plates

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

- a. The individual side plates are separated by Type 304L stainless steel shim stock approximately thirty thousandths of an inch (0.030 in.) thick.
- b. 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.
- c. A maximum of fifteen side plates are stacked with the alumina-coated shims between each plate.

Caution: A dried 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 dry hydrogen. A flow rate sufficient to bright anneal stainless steel is required.

Equipment:

- Furnace capable of attaining and holding two thousand and fifty degrees fahrenheit plus or minus twenty-five degrees fahrenheit ($2050^{\circ}\text{F} \pm 25^{\circ}\text{F}$) with hydrogen atmosphere of minus eighty degrees fahrenheit (-80°F) dewpoint and an inert gas source. Accurate dewpoint measuring instrument.

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 shall not be deeper than one thousandth of an inch (0.001 in.).

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

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: - 1. Sampling

Every tenth plate or one plate from each manufacturing lot shall be counted.

2. 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 U-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 one hundred and fifty (150) disintegrations per minute per square foot of plate surface.

If the tested plate exceeds the maximum allowable, the entire lot shall be counted. If any other plate exceeds the maximum, spot checks are made of plates from the previous lot. In addition, the plate identity and amount of alpha contamination will be recorded.

Calibration: - The alpha counting device shall be calibrated, using a standard source previously standardized by the National Bureau of Standards.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

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:

- 1. 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 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.

- 2. Combs

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

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

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.

Process: - Combs are normally made from sheet or strip stock of suitable thickness. The length is milled to final size. The width is milled one quarter inch (1/4 in.) oversize 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) to 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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - End Box Machining

Purpose: - This specification covers the machining of the end boxes prior to attachment, by welding, to the fuel assemblies. 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. 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 one 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. The surfaces are then straddle milled.

The fixture is also used to locate and hold the end boxes during machining of the end connections which are inserted into the welded 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 welded fuel assembly. Hand finishing of the unmachined inside surfaces may be necessary to obtain the required finish.

Equipment: - Milling machine.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: - Machined End Box Inspection
- Purpose: - This specification covers the visual and dimensional inspection of machined end boxes.
- Process: - The machined castings are visually inspected for surface imperfections that have not cleaned-up during machining. Any surface imperfection when hand worked, shall not result in an undersize dimension.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Fabrication of Welded Fuel Elements

Purpose: - These specifications cover materials and processes required to produce completed fuel elements.

Equipment Requirements:

1. Welding Fixture

The fixture shown in Figure 6 is a high strength aluminum alloy casting two and one-half inches (2-1/2 in.) thick by fifteen inches (15 in.) wide by thirty nine inches (39 in.) long. The dimensions of the cutout are five and one-half inches (5-1/2 in.) by thirty two inches (32 in.). A one inch (1 in.) by two and six hundred and sixty-five thousandths (2.665 in.) by twenty-nine inches (29 in.) stainless steel backup bar is bolted to one inside surface of the fixture. A moveable stainless steel pressure plate of the same dimensions as the backup bar and containing accurately machined guide pins is located on the opposite inside surface. Stainless steel holddown bars, one half inch (1/2 in.) wide, are placed across the fixture from the pressure plate to the backup bar to hold the side plates against the fuel plates during the welding operation. The ends of the hold-down bars are slotted to allow movement of the pressure plate during assembly.

2. Spacers

The spacers, sandwiched between shims, shown in Dwgs. A9-13-2183 and A9-13-2184, are placed between fuel plates in order to insure proper alignment of the fuel plates in the side plate grooves and to control distortion during the welding operation. The shims are held in position while the spacers are removed.

3. Welding Power Source

The power source is a 200 or 300 amp DC or AC-DC rectifier equipped with a three stage weld sequence tier for accurate control of the welding cycle. Refer to Figure 7.

4. Automatic Welding Head

An automatic welding head shall be used to maintain constant arc voltage and arc length. Refer to Figure 8. Provide an

index adjustment for welding in the head or in the fixture between hold-down bars. The drive motor in the automatic head is used to position the torch vertically, allowing welding between the holding bars on the fixture.

5. Travel Carriage

The travel carriage is equipped with an electronic governor to maintain constant speed regardless of varying load conditions. The carriage must be mounted on an accurately machined track, in order to maintain straight line travel and precise alignment of the welding torch with the fuel plate being welded. Refer to Figure 8.

6. Spacer Removal Unit

A means of removing spacers from the element, after welding, must be provided. The unit shown in Figure 9 is one method of accomplishing this task. The element is held in position by the four bolts on the pressure plate and the pressure plate assembly is indexed transversely to remove each spacer individually. A six inch (6 in.) diameter double acting air cylinder, thirty inches (30 in.) in length and cushioned on both ends, is used as a power source.

Operation of the air cylinder is controlled by electrically operated solenoid valves.

7. Plate Spacing Gage

A plate spacing gage such as shown in Figure 10 or equivalent must be used to measure fuel plate spacing at specified locations within the elements. The unit in Figure 10 contains an elliptical probe with a minor axis dimension of one tenth of an inch (0.100 in.) and a major axis dimension of one hundred and eighty thousands of an inch (0.180 in.) placed on one end of a ninety thousandths of an inch (0.090 in.) diameter shaft. A pointer is connected to the opposite end of the shaft and rotated on a five inch (5 in.) radius on the frame of the unit. The unit is calibrated by rotating the ellipsoid within a micrometer placed perpendicular to the probe. The calibrated measurements are placed on the radius of the plastic frame. A one ounce (1 oz.) weight suspended from a two inch (2 in.) diameter pulley on the shaft assures that the amount of torque applied to the shaft is constant for all measurements.

Fabrication Procedure:

1. Cleaning

All component parts and fixtures are cleaned with acetone prior to assembly. Care should be exercised to assure that all foreign matter is removed from the side plate grooves. Cleanliness is maintained throughout fabrication by keeping the assembly under cover during all times that work is not being performed. Workmen handling the fixtures, component parts or finished elements must wear clean, white, cotton gloves to prevent contamination by dirt, oil, grease, finger prints or other foreign matter. After fabrication, the assembly is wrapped in polyethylene film to maintain cleanliness during shipment.

2. Assembly - Stationary Fuel Element

The stationary fuel element is assembled as follows:

- a. Place all hold-down bars on the bottom of the fixture and hand tighten.
- b. Place one side in the fixture, resting on the hold-down cross bars.
- c. Alternately place fuel plates, shims and spacers in the fixture. Be certain that all fuel plates fit in the grooves properly. The spacers rest on the special cross-bars at each end of the fixture. Refer to Figure 11.
- d. Align fuel plates within fixture.
- e. Using the top side plate grooves as a guide, compress the assembly with the moveable pressure plate, until the fuel plates match the side plate grooves.
- f. Install the top side plate and working from one end, tighten holddown bars securely.
- g. Turn the fixture over and tighten the hold-down bars on the opposite side of the fixture.
- h. Install shims on the ends of the element between the spacers and the section of the side plates which extend beyond the fuel plates.

- i. Seal the ends of the assembly with masking tape and provide for inert-gas shielding on the inside of the element, (between spacers and inside surface of side plate).

3. Assembly-Control Rod Element

The control rod fuel element is assembled in the same manner as the stationary element with the following exceptions.

- a. A spacer is placed between the back-up bar on the fixture and the first fuel plate and also between the last fuel plate to be inserted and the moveable pressure plate in order that the same fixture can be used for both stationary elements and control rod elements.
- b. The hold-down bars are turned over to compensate for the shorter height of the control rod element. Bars are asymmetrically designed for both element sizes.

4. Welding of Fuel Plates to Side Plates

- a. Welding of the assembly conforms with the welding procedure in Table 1 and must be an automatic operation for each individual fuel plate.
- b. Arc voltage must be preset on the automatic welding lead control within a one volt range.
- c. Welding speed must be adjusted to provide uniform motion of the welding head between hold-down bars during the welding cycle.
- d. Alignment of the electrode with the plate being welded is done manually or by micrometer indexing. The side plates contain a slight projection after machining. When the electrode is aligned manually, adjustment is made to the center of this projection.
- e. Argon is injected during current decay.
- f. Weld pitch is 1/2-3 and staggered on alternate fuel plates. Welds placed on the opposite side of the element must be placed between the welds on the first side. Refer to Figure 12 for weld sequence pattern.

TABLE 1
RECOMMENDED WELDING PROCEDURE
TYPE 3 STATIONARY AND CONTROL ROD FUEL ELEMENTS

Process:	Automatic Inert Gas Shielded Tungsten Arc
Power Source:	DC or AC-DC Rectifier Type Welding Machine
Welding Torch:	Automatic Welding Head
Type of Current:	Direct, Straight Polarity
Starting Current & Duration:	$31 \pm .5$ amperes, 1.5 sec
Welding Current & Duration:	$29 \pm .5$ amperes, 2.5 sec
Finishing Current & Duration:	10 amperes or lower (current decay), 1 sec
Arc Voltage:	10.0 - 11.0 volts
Primary Shielding:	15-20 cfh He-A (through welding torch)
Secondary Shielding:	10 cfh Argon or He-A 75 Helium, 25 Argon (to purge inside of element)
Electrode:	1/16 in. diameter 2% thoriated Tungsten, sharpened to a point
Welding Torch Nozzle:	3/8 in. diameter orifice
Weld Pitch:	1/2-3
Sensitivity:	Low Range (voltage sensing reaction of automatic head)
Filler:	None
Welding Speed:	9 inches/min

Figure 6. Welding Fixture with Stationary Element Assembled

NOTE
BREAK SHARP EDGES
REMOVE ALL BURRS

MATERIAL:
TOOL STEEL

ALCO		ALCO PRODUCTS INC. NUCLEAR POWER ENGR DEPT. SCHENECTADY N.Y. U.S.A.	
SCALE	REF	DR	WILLIAMS 6-27-60
		TR	
		CHK	DECKER 3-19-62
		APPR	Connelly 2/19/62
		APPR	
		NET	Reel 6-27-60
NAME		SPACER	
PART NO		A9-13-2183

NOTE
BREAK SHARP EDGES
REMOVE ALL BURRS

MATERIAL:
TYPE 302 STAINLESS
STEEL

ALCO		ALCO PRODUCTS INC. NUCLEAR POWER ENGR. DEPT SCHENECTADY, N.Y., U.S.A.	
SCALE	REF	DR	WILLIAMS 6-27-60
		TR	
		CHK	DECKER 3-19-62
		APPR	Connolly 3/19/62
		APPR	
		MET.	POB 6/27/60
NAME		SHIM	
PART NO		A9-13-2184

Figure 7. Power Source and Weld Sequence Timer

Figure 8. Automatic Welding Head Mounted on Side Beam Carriage

Figure 9. Spacer Removal Unit

Figure 10. Fuel Plate Spacing Gauge

Figure 11. Welding Fixture with Top Side Plate Removed to Show Position of Spacers

Figure 12. Weld Sequence Pattern (entire fuel plate welded)

Title: - Inspection of Welded Fuel Assemblies after Welding

Purpose: - This specification covers the inspection of the welded fuel assemblies and contains three parts. The first part covers visual inspection, the second covers the dye penetrant inspection of the welds and the third covers dimensional inspection.

Process: - A) Visual Inspection

All welds shall exhibit conformance to the highest standards consistent with the application.

B) Dye Penetrant

The welded side plates are dye penetrant tested according to the procedures of MIL STD 271A (SHIPS) with the exception that the minimum penetration time will be twenty (20) minutes.

C) Dimensional

The welded fuel assemblies are dimensionally inspected for water channel spacing, assembly width and weld bead location.

1. Stationary Fuel Assemblies

a. Channel Spacings

The water channel spacings shall be measured at one inch (1 in.) intervals along the length at the plate centerline for each channel. The first and last readings are taken one inch (1 in.) from the respective plate ends. Maximum individual deviation allowable is plus or minus eight thousandths of an inch (± 0.008 in.) from the nominal of one hundred and twenty three thousandths of an inch (0.123 in.).

Maximum average deviation allowable for any channel is plus or minus four thousandths of an inch (± 0.004 in.) from the nominal of one hundred and twenty three thousandths of an inch (0.123 in.).

Any channel with deviations in excess of the allowable is not acceptable.

b. Assembly Width

The stationary fuel assemblies are measured for width across the side plates at six locations along the top and bottom of the fuel assembly. The measurements are at locations of one (1), six (6), eleven (11), sixteen (16), twenty-one (21), and twenty-six (26) inches from the numbered end of the fuel assembly and at a point one-half inch ($1/2$ in.) from the side plate edges. Any deviations beyond the tolerances indicated on the applicable drawing is not acceptable.

c. Weld Bead Location

The centerlines of all fuel plate to side plate welds, as measured from the weld bead on the side surface, shall be within sixteen thousandths of an inch (0.016 in.) of the centerline of the side plate groove.

2. Control Rod Fuel Assembly

a. Same as C-1-a

b. Same as C-1-b except the last reading will be twenty-three inches (23 in.) from the numbered end.

c. Same as C-1-c.

D) Contour or Ripple of Outside Fuel Plates

The contour or ripple of the outside fuel plates of the control rod fuel assembly is measured along the centerline of the fuel plates at one inch (1 in.) intervals starting from the numbered end of fuel assembly. The first reading is one inch (1 in.) from end of fuel assembly and the last reading one inch (1 in.) from the other end. The measurements are made with a depth micrometer referenced from the side plate edges. Any local deviation shall not exceed plus or minus eight thousandths of an inch (± 0.008 in.) or an average deviation of plus or minus four thousandths of an inch (± 0.004 in.) from the nominal dimension of sixty-four thousandths of an inch (0.064 in.).

Title: - Welding of Comb and Plate Extensions, Control Rod Fuel Element

Purpose: - This specification covers the welding of the comb to the fuel plate extensions and, after assembly, the welding of the fuel plate extensions to the side plates and the comb to the outside fuel plates.

Process: - A) Welding of Comb to Plate Extensions

The comb shall be welded to the two plate extensions in an appropriate fixture. Welding is done using the tungsten inert gas process, with no filler metal added.

B) Welding of Plate Extensions and Combs to Fuel Assembly

After welding the comb to the plate extensions, the sub-assembly is properly fitted in the fuel assembly. The fuel assembly is then placed in the fuel element welding fixture and the plate extensions are welded to the side plates in the same manner as that used in welding the fuel plates, according to the welding procedures in Table 1, (ALCO-NPE Specification WFE-61). The fuel assembly is removed from the fixture and the comb is tack welded to the outside fuel plates by the tungsten inert gas process.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: - Welding of End Boxes to Stationary Fuel Assembly
- Purpose: - This specification covers the assembly and tungsten inert gas welding of the end boxes to the stationary fuel assembly to form a stationary fuel element.
- Process: - A combination assembly and welding jig is used for this operation. The jig is composed of a base plate with one end stock solidly mounted and the other end stock movable, to allow closing together of the end stocks after the end boxes have been slipped over the mandrels. The end boxes are engaged into the female section of the fuel assembly and the end box is entered over the mandrel of the stationary end stock. The other end stock is slid toward the solid end and the other end box entered over the other mandrel. The centerlines of the mandrels have to be concentric to the centerlines of the end boxes and the fuel element centerline. Clamps are mounted over the ends of the side plates and the end boxes are 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. After set up, the fuel assemblies are checked for concentricity before welding. The fuel assemblies are butt welded to the end boxes using a tungsten inert-gas process with argon gas and Type 348 bare filler wire. Only the side plates are welded to the end boxes, using the following procedures: 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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Final Machining of Fuel Element and Accessory Installation

Purpose: - This specification covers the final machining of the side plate edges and fuel element end boxes (ALCO-NPE Specification No.FE-40) 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 first machining operation is the removal of excess side plate material. The fuel element is mounted on the table of a vertical milling machine, supported by the flat portion of the end boxes and clamped to the table. The excess material is removed by means of a fly cutter tool. After one side is finished the element is turned one hundred eighty degrees (180°) on its longitudinal axis and the same operation performed on the second side. In the second operation the fuel element is placed in a lathe with the inlet and 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 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 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.

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 the applicable 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 and Fabricator's symbol 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

- Title: - Final Inspection of Completed Stationary Fuel Element
- Purpose: - This specification covers the dimensional inspection of completed stationary fuel elements. The fuel element is subsequently cleaned, checked for surface contamination and packaged for shipment.
- Process: - The final inspection consists of the following:
- A) Concentricity
- An inspection ring is placed around each end box. Both rings are made with identical outside diameters three and one-half inches (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 variation allowable is two thousandths of an inch (0.002 in.) total indicator run-out.
- B) Contour
- The contour of the outer fuel plates is measured along the centerline of the plates at one inch (1 in.) intervals starting from the numbered end of the fuel element. The first reading is three inches (3 in.) from the end box casting and progressing to three inches (3 in.) from the other end box. The measurements are made with a dial indicator and the indicator zero being taken at the first measurement. The fuel element is mounted as in paragraph A. The nominal dimension from the outer fuel plate surfaces to the theoretical centerline of the fuel element is one inch four hundred and six thousandths of an inch (1.406 in.). Any local deviation shall not exceed plus or minus eight thousandths of an inch (± 0.008 in.). The average deviation shall not exceed four thousandths of an inch (0.004 in.).
- C) Perpendicularity
- 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-makers 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.).

D) Length Between Shoulders

The length between shoulders of the end boxes is measured with a thirty-six inch (36 in.) vernier caliper. The nominal overall fuel element length is also measured in this manner. The tolerance for the measurements are plus or minus ten thousandths of an inch (0.010 in.).

E) Distortion

Gross distortion of the completed fuel elements is checked by passing the element through a go-no-go box approximately ten percent (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.

- Title: - Preparation of Fuel Elements for Shipment
- Purpose: - This specification covers chemical cleaning, checking for contamination and packaging for shipment, the finished fuel elements.
- 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 percent (10%) nitric acid (HNO_3)-water (H_2O) solution for ten minutes (10 min), then rinsed in hot running water. Immediately after drying, the fuel elements are checked by the Fabricator's Health Physics Department for cleanliness and, if acceptable, each is inclosed in a plastic sheath, which must be 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.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

Title: - Inspection of Fuel Elements Selected for Post Irradiation Examination Studies

Purpose: - This specification covers the special inspection requirements of fuel elements that will be examined after removal from the reactor. This inspection will entail:

1. Fuel Plate Thickness
2. Coolant Channel Spacings
3. Fuel Element Width and Side Plate Profile
4. Fuel Element Height and Outside Fuel Plate Profile
(i.e. the distance between the bottom of the bottom fuel plate to the top of the top fuel plate) and the profile of the top and bottom fuel plates along the centerline and one and one quarter inch (1-1/4in.) from centerline on each side of centerline.

Process: - A) Stationary Fuel Element

1. Fuel Plate Thickness

The thickness of each fuel plate is measured before assembly, along the longitudinal centerline and along lines one inch (1 in.) each side of the centerline at one inch (1 in.) intervals from the numbered end of the fuel plate. These measurements are made with a deep throated one inch (1 in.) micrometer or similar measuring instrument. These shall be recorded to the nearest one ten thousandth of an inch (0.0001 in.).

2. Coolant Channel Spacings

The coolant channel spacings are measured after the welding of the fuel assembly. The channel spacings for every channel are measured at one inch (1 in.) intervals along the longitudinal centerline and along lines one inch (1 in.) each side of the centerline. The measurements are made with a calibrated probe or by a measuring instrument giving a continuous strip chart read-out. The readings start at one inch (1 in.) from the channel end and progress to one inch (1 in.) from the other end of the channel. All readings are located from the numbered end of the fuel elements. The coolant channel readings shall be recorded to the nearest one thousandth of an inch (0.001 in.). This gives a total of eleven hundred and twenty two readings (1122).

3. Fuel Element Width and Side Plate Profile

The fuel element width and side plate profile measurements are made after the fuel element fabrication has been completed. The width is measured with a three inch (3 in.) micrometer at one inch (1 in.) spacings along the longitudinal centerline of the side plates and along lines one and one-quarter inches (1-1/4 in.) each side of the centerline. This makes a total of eighty one (81) readings for each stationary fuel element. The side plate profile is measured by placing the fuel element on parallel blocks resting one side plate on the blocks and using the first reading on the centerline one inch (1 in.) from the numbered end of fuel element as the reference point to zero indicator. Traverses are made with a surface gauge and dial indicator at the same points as noted in the above paragraph for fuel element width. After completion of one side, the fuel element is turned over to the other side plate and the measurements repeated giving a total of one hundred and sixty-two (162) readings. The width and side plate profile readings shall be recorded to the nearest one-thousandth of an inch (0.001 in.).

4. Fuel Element Height and Outside Fuel Plate Profile

The fuel element height is calculated from measurements made by measuring the distance from the side plate edges to the outside surface of the outer fuel plates. Measurements are made at one inch (1 in.) intervals starting at one inch (1 in.) from the numbered end of the fuel element along the longitudinal centerline of the fuel plate and along lines one inch (1 in.) each side of this centerline.

Measurements are made with a depth micrometer using the side plate edges as the reference points. The height and profile measurements are recorded to the nearest one thousandth of an inch (0.001 in.). A total of one hundred sixty-two (162) measurements are made on the two outside fuel plates.

The side fuel plate profile measurements are made with a surface gauge and a dial indicator. The profile measurements of the fuel plates are done the same as the side plate profile measurements. The following is a listing of necessary measurements for stationary fuel elements:

<u>Measurement</u>	<u>Number of Readings</u>
Side Plate Width	81
Side Plate Profile	162
Fuel Plate Height	162
Fuel Plate Profile	162
Coolant Channels	1112
Fuel Plate Thickness	<u>1218</u>
Total	2897 measurements

B) Control Rod Fuel Elements

1. Fuel Plate Thickness

The thickness of each fuel plate is measured before assembly along the longitudinal centerline and along lines three-quarters of an inch ($3/4$ in.) each side of the centerline at one inch (1 in.) intervals from the numbered end. The measurements are made with a deep throated micrometer or similar measuring instrument. These shall be recorded to the nearest ten thousandth of an inch (0.0001 in.). The total number of measurements for the fuel plate for a control rod fuel element is one thousand and fifty six (1056).

2. Coolant Channel Spacing

The coolant channel spacings are measured after the welding of the fuel assembly. The channel spacings for every channel (15) are measured at one inch (1 in.) intervals along the longitudinal centerline and along lines three-quarters inch ($3/4$ in.) each side of the centerline. The measurements are made with a calibrated probe or by a measuring instrument giving a strip chart readout. The readings start at one inch (1 in.) from the handle end of the fuel assembly and progress to within one inch (1 in.) of the other end. These shall be recorded to the nearest one thousandth of an inch (0.001 in.). This gives a total of nine hundred and ninety (990) readings.

3. Fuel Element Width and Side Plate Profile

The fuel element width and side plate profile measurements are made after the fuel element fabrication has been completed. The width is measured with a three inch (3 in.) micrometer at one inch (1 in.) spacings along the longitudinal centerline of

the longitudinal centerline of the side plate and along lines one inch (1 in.) each side of the centerline. This makes a total of seventy (70) measurements for each control rod fuel element. All measurements are located from the handle end on the control rod fuel elements.

The side plate profile is measured by placing the fuel element on parallel blocks resting one side plate on the blocks and using the first reading of the centerline traverse as the reference point to zero indicator. Traverses are made with a surface gauge and dial indicator at the same points as noted in the preceding paragraph. When one side plate measurements are completed, the fuel element is turned over and the measurements repeated giving a total of one hundred and forty (140) measurements. The width and side plate profile readings shall be recorded to the nearest one thousandth of an inch (0.001 in.).

4. Fuel Element Height and Outside Fuel Plate Profile

The fuel element height is calculated from measurements made by measuring the distance from the side plate edges to the outside surface of the outer fuel plates. Measurements are made at one inch (1 in.) intervals starting at one inch (1 in.) from the handle end of the fuel plates along the longitudinal centerline of the fuel plates and along lines one inch (1 in.) each side of the fuel plate centerline. Measurements are made with a depth micrometer using the side plate edges as the reference point. The height and profile measurements are recorded to the nearest one thousandth of an inch (0.001 in.). A total of one hundred thirty-two (132) measurements are made on the top two outside fuel plates.

The outside fuel plate profile measurements are made with a surface gauge and a dial indicator. The profile measurements of the outside fuel plates are done the same as the side plate profile measurements.

The following is a listing of necessary measurements for a control rod fuel element.

<u>Measurement</u>	<u>Number of Readings</u>
Side Plate Width	70
Side Plate Profile	140
Fuel Plate Height	132
Fuel Plate Profile	132
Coolant Channel	990
Fuel Plate Thickness	<u>1056</u>
Total	2520 measurements

C) Marking of Side Plates

To aid in the disassembly of an irradiated fuel element, it is necessary to mark the outside of the fuel element side plates with shallow machined grooves to locate the center of the water or coolant channels. These guide marks will facilitate the placement of the milling machine cutters during the disassembly operation.

The side plates of the selected fuel elements will be marked at the centerline of each coolant channel with a mill cutter to a depth of one thousandth of an inch (0.001 in.) for three inches (3 in.) from each end. This operation could be done with the side plate machining set up, using the side plate milling cutter, and must be performed prior to flat annealing.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: Attaching Gusset Plate to Grooved Side Plate on Control Rod Fuel Element
- Purpose: - This specification covers the attachment of the stainless steel gusset plates to the grooved face of the side plates.
- Process: - The gusset plate is machined per the applicable drawing and attached to the grooved face of the side plate by Tungsten Inert Gas welding. The shouldered end of the gusset, with the channeled side facing the grooved side of the side plate, is centered at the square end by a "C" clamp. A small spacer bar is placed inside the channel of the gusset plate, between it and the side plate, to avoid deformation of the side plate during clamping. After checking for proper alignment, the gusset plate is heliarc welded using Type 347 stainless steel filler rod at the four gusset to side plate joints.
- Equipment: - Heliarc welder

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: - Handle Pin Attachment
- Purpose: - This specification covers the attachment of the handle pin to the gusset plates. This completes the handle used for supporting the fuel element during nuclear reactor refueling.
- Process: - The finish machined handle pin is positioned in the holes provided in the gusset plates and heliarc welded in position.
- Equipment: - Heliarc welder

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

- Title: - Final Inspection of Completed Control Rod Fuel Element
- Purpose: - This specification covers the dimensional inspection of completed fuel elements. The fuel element is subsequently cleaned, checked by the Fabricator's Health Physics Department for surface contamination and packaged for shipment.
- Process: - Gross distortion of the completed fuel elements is checked by passing the element through a go-no-go box approximately ten percent (10%) longer than the fuel element, with inside dimensions equal to the maximum free path allowable as shown in the fuel element drawing. The fuel element must pass freely through this box for acceptance.

The handle is inspected to assure that all dimensions as shown on Alco Drawing D9-13-1047 are met.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

IV. PACKAGING AND PACKING FOR SHIPMENT

After meeting all applicable requirements, each assembly shall be inspected for scratches, dents and other mechanical damage and shall then be individually wrapped in polyethylene film in preparation for shipment.

Elements must be packed to prevent damage in shipment and meet A.E.C or Bureau of Explosives requirements and in accordance with TID 7016 and 7019, published by the Technical Information Division of the U.S.A.E.C.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

V. 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 uranium dioxide and the burnable poison in the form of natural ZrB_2 , it is necessary to determine by calculation the quantities of these materials which are to be incorporated into each fuel core. Each batch of as-received uranium dioxide is assayed for total uranium content as well as for isotope concentration of uranium 235. Likewise the concentration of boron and boron 10 in the zirconium diboride is accurately determined.

A Typical Loading - Stationary Fuel Plate

U-235	46.30 gms
B-10	0.0498 gms

The active core volume is -

$$.030" \times 22" \times 2.670" = 1.762 \text{ in.}^3 = 28.874 \text{ cm}^3$$

$$\text{Final density is } \approx 95\% \therefore \text{Core V} = 27.430 \text{ cm}^3$$

$$\text{UO}_2 \text{ volume} = \frac{\text{U-235 in gms}}{\text{wt. \% U}_{\text{in}} \text{ UO}_2 \times \text{w \% U-235 in U}_T \times 10.8 \text{ density}}$$

$$V = \frac{46.30}{.876 \times .931 \times 10.8} = 5.208 \text{ cm}^3 \text{ or}$$

$$\text{ZrB}_2 \text{ volume} = \frac{\text{B-10 in grams}}{\text{wt \% B in ZrB}_2 \times \text{w \% B-10 in B}_n \times 6.09 \text{ density}}$$

$$V = \frac{.0498}{.191 \times .185 \times 6.09} = .231 \text{ cm}^3$$

$$\text{The matrix steel volume} = \text{Core Vol} - (\text{UO}_2 V + \text{ZrB}_2 V)$$

$$\text{Matrix V} = 27.430 - (5.208 + .231) = 21.991 \text{ cm}^3$$

$$\text{Matrix weight} = V \times \text{density}$$

$$\text{Matrix weight} = 21.991 \text{ cm}^3 \times 7.8 \text{ gram/cc} = 171.53 \text{ gms}$$

When the UO_2 volume is decreased because of higher enrichment level or higher U in UO_2 ratio the decrease in UO_2 volume is replaced with stainless steel matrix material. The boron volume is so small that it is not necessary to change the amount of matrix material.

FUEL AND POISON MATERIAL

The fuel loading is stated in grams of U-235, the amount of UO_2 necessary to obtain the correct amount of U-235 is calculated by the following:

$$\text{UO}_2 = \frac{\text{U-235 loading in grams}}{\text{w/o U in UO}_2 \times \% \text{ enrichment}}$$

$$\text{UO}_2 = \frac{46.30 \text{ gms}}{.878 \times .931} = 56.67 \text{ gms}$$

The burnable poison loading is stated in grams or milligrams of boron 10. The amount of ZrB_2 necessary to retain the correct amount of boron 10 is calculated by the following:

$$\text{ZrB}_2 = \frac{\text{B-10 loading in grams} -}{\text{w/o B in ZrB}_2 \times \text{w/o B-10 in B}_n}$$

$$\text{ZrB}_2 = \frac{0.0498 \text{ gms}}{.189 \times .185} = 1.423 \text{ gms}$$

The control rod fuel plate calculations are identical with the stationary except that the dimensions for the control rod fuel plate are used for the core volume. The suppressor loadings are discussed in ALCO-NPE Specifications S-5.

VI. LIST OF DRAWINGS (Alco Products, Inc., Drawings)

<u>Title</u>	<u>Drawing No.</u>	<u>Revision</u>
<u>STATIONARY FUEL ELEMENTS</u>		
Assembly Fuel Element	R9-13-1052	A 2-20-62
Long Fuel Plate	C9-13-2210	B 2-22-62
Short Fuel Plate	C9-13-2211	B 2-19-62
Side Plate	D9-13-2207	A 2-14-62
Comb	C9-13-2212	A 2-22-62
End Box Inlet	C9-13-2208	A 2-9-62
End Box Outlet	C9-13-2209	A 2-16-62
Dowel	A9-13-2024	D 2-7-62
Spring	B9-49-2103	E 2-19-62
<u>CONTROL ROD FUEL ELEMENTS</u>		
Fuel Element	D9-13-1047	C 2-20-62
Comb	B9-13-2195	A 2-19-62
Plate Extension	B9-13-2194	A 2-19-62
Fuel Plate	B9-13-2213	B 2-19-62
Side Plate	C9-13-2214	B 1-9-62
Handle	A9-13-2193	C 2-19-62
Pin, Handle	A9-13-2077	C 2-19-62

DATE	LET.	REVISION RECORD	AUT.	DR.	CHK.
2-22-62	B	REDRAWN & "SM" TYPE			
		3 CORE "MRS" SM-1			
		CORE III & SM-1A			
		CORE III .60-0397	JPC	MP	EW

PART NO.
C9-13-2210

SM TYPE 3 CORE

SECTION A-A
SCALE 4 x SIZE

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE ±

✓ FINISH AS INDICATED
IN MICROINCHES.
(1) MACHINE FINISH - ROUGH
(10) PLANE CUT OR SAW

ALCO		ALCO PRODUCTS, INC.	
		NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.	
SCALE	FULL	DR.	F.H.W. 1-8-62
MATERIAL SPEC.	R2-13-1052	CHK.	DEC 28 1-8-62
SEE FUEL ELEMENT SPEC.		APPR.	CONNOLLY 1-9-62
		MEET.	ELFORD 1-9-62
NAME LONG FUEL PLATE (STATIONARY FUEL ELEMENT)			
PART NO. C9-13-2210			

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
2-19-62	B	REDRAWN - SM TYPE			
		3 CORE WAS SM1	JPC		
		CORE III & SMIA CORE III	550	JP FW	

CORE TO BE CENTERED
IN PLATE WITHIN .030 Laterally

PART NO.
C9-13-2211

SM TYPE 3 CORE

SECTION - "A-A"

BRING SHARP EDGES
REMOVE ALL BURRS

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

- ✓ FINISH AS INDICATED
IN DIMENSIONS.
- (11) MACHINE FINISH - ROUGH
- (11) FLAME CUT OR SAW

ALCO		ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.	
SCALE	FULL	DR.	E. H. W.
MATERIAL SPEC.	SEE FUEL ELEMENT SPEC	TR.	1-4-62
NAME	SHORT (FUEL ELEMENT, FUEL PLATE STATIONARY.)	CHK.	DECKER
PART NO.	C9-13-2211	APPR.	1-8-62
		APPR.	1-9-62
		MET.	1-9-62

DATE	REV.	REVISION RECORD	AUTH.	DR.	CHK.
2-14-62	A	REDRAWN: SM TYPE 3 CORE WAS: SM CORE III # SMIA CORE III (5587)	JAC	JPE

SECTION A-A
SCALE - 4 x SIZE

SM TYPE 3 CORE

PART NO. D9-13-2207

- UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE ± $\frac{1}{64}$
- ✓ FINISH AS INDICATED
IN MICRONS
 - (1) MACHINE FINISH - ROUGH
 - (10) PLANE CUT OR SAW

ALCO		ALCO PRODUCTS, INC.	
		NUCLEAR POWER ENGINEERING DEPT.	
		SCHENECTADY, N. Y., U. S. A.	
SCALE	FULL	DR.	EHW
MATERIAL SPEC.	RS-13-1052	TR.	1-4-62
SEE FUEL ELEMENT SPEC.		CHK.	DECKER 1-8-62
		APPR.	T. F. CONNELLEY 1-9-62
		MET.	E. C. EDGAR 1-9-62
NAME		FUEL ELEMENT	
SIDE PLATE		STATIONARY	
PART NO.		D9-13-2207

DATE	REV.	REVISION RECORD	AUTH.	DR.	CHK.
2-22-62	A	REDRAWN & SM TYPE			
		TYPE 3 CORE WAS			
		SM CORE III & SM-1A			
		CORE III EGO-0397	JPC	H.F. EW	

PART NO. C9-13-2212

SM TYPE 3 CORE

ALCO		ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.		
SCALE	1/8"	DR.	E.N.W.	1-462
MATERIAL SPEC.	DOUBLE 10-13-1052	TR.		
SEE FUEL ELEMENT SPEC.		CHK.	DECKER	1-8-62
		APPR.	JPC	1-9-62
		APPR.		
		MET.	E.C. EDGAR	1-9-62
NAME FUEL ELEMENT COMB (STATIONARY)				
PART NO. C9-13-2212				

BREAK SHARP EDGES
REMOVE ALL BURRS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE:

- ✓ FINISH AS INDICATED IN MICROFINISH
- 1/1 MACHINE FINISH - ROUGH
- 1/10 FLAME CUT OR SAW

NOTES:
BLEND UNIFORMLY FROM $\frac{1}{8}$ " RADIUS AT POINT "X"
TO $\frac{1}{8}$ " RADIUS AT POINT "Y" AS SHOWN IN SECTION "A-A"

SM TYPE 3 CORE.

ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y. U. S. A.	
SCALE	FULL	REV.	29-13-1052
MATERIAL SPEC. SEE FUEL ELEMENT SPEC.		DR.	E.H.W. 1-4-62
		CHK.	
		THR.	DECKER 1-8-62
		APPR.	T.F. GORRELLY 1-9-62
		APPR.	GORRELLY
		MET.	E.E. EDGAR 1-9-62
NAME FUEL ELEMENT END BOX			
(INLET)			
PART NO. C9-13-2208			

DATE	LET	REVISION RECORD	AUTH.	DR.	CHE.
2-10-62	A	REDRAWN; "SM TYPE 3 CORE" WAS SM-1 CORN III # SM-1A CORE III	JTC		
			150	JP	EW
			2597

PART NO. C9-13-2209

NOTE:
BLEND UNIFORMLY FROM A 1" RADIUS AT
POINT "X" TO A 1/8" RADIUS AT POINT "Y"

LOCUS LINE OF CENTERS
OF BLEND RADIUS

SM TYPE 3 CORE

BRKAW SHARP EDGES
REMOVE ALL BURRS

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

✓ FINISH AS INDICATED
IN CHECKSHEET.
① MACHINE FINISH - ROUGH
⑩ FLAME CUT OR SAW

ALCO		ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y. U. S. A.	
SCALE FULL	REV. 2-9-62-1057	DR. G.H.W.	1-4-62
MATERIAL SPEC.		TR.	
SEE FUEL ELEMENT. SPEC.		CHK. DECKER	1-8-62
		APPR. J.E. CONTALDO	1-9-62
		APPR.	
		MET. B.C. EDGAR	1-9-62
NAME: FUEL ELEMENT END BOX (OUTLET)			
PART NO. C9-13-2209			

A9-13-2024

[illegible]

SM TYPE 3 CORE

NOTES:

125 $\sqrt{\quad}$ ALL OVER

**BREAK SHARP EDGES
REMOVE ALL BURRS**

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

✓	FINISH AS INDICATED
IN MICROINCHES.
f_1	MACHINE FINISH - ROUGH
f_{10}	FLAME CUT OR SAW

ALCO

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPT.
SCHENECTADY, N. Y., U. S. A.

SCALE	REF.			
TWICE SIZE	R9-13-1003	DR.	G.E.WEINBENDER	12-28-55
MATERIAL SPEC. SEE FUEL ELEMENT SPEC.		TR.		
		CHK.	GESTWICKI	12-28-55
		APPR.	TULLY	12-28-55
		APPR.	T.F.CONNOLLY	1-9-62
		MET.	EDGAR	8-21-59

NAME DOWEL
(FUEL ELEMENT STATIONARY)

PART NO.

A 9-13-2024

SM TYPE 3 CORE

DIA. OF WIRE NO. 6 W&M GAUGE .192 INCHES
 INSIDE DIA. OF COILS ----- 2.491 INCHES
 OUTSIDE DIA. OF COILS ----- 2.875 INCHES
 SPRING WORKS ON ROD ----- 2.438 IN. DIA.
 NUMBER OF FREE COILS ----- 7 COILS
 TOTAL NUMBER OF COILS ----- 9 COILS
 FREE LENGTH ----- 2.375 INCHES

SPRING IN PLACE
 LENGTH OF SPRING IN PLACE ----- 1.875 INCHES
 LOAD ON SPRING IN PLACE ----- 6.3 LBS.
 DEFLECTION OF SPRING IN PLACE ----- .500 INCHES

NORMAL OPERATING CONDITIONS
 LENGTH OF SPRING UNDER NORMAL MAX LOAD - 1.875 INCHES
 NORMAL MAX. LOAD & HOW APPLIED ----- 63 LBS STATIC
 DEFLECTION AT NORMAL MAX. LOAD ----- .500 IN.
 STRESS AT NORMAL MAX. LOAD ----- 6,080 LBS/SQ. IN.
 SOLID HEIGHT = 1.728, STRESS AT SOLID HEIGHT ----- 7,860 LBS/SQ. IN.
 SPRING WOUND RIGHT OR LEFT HAND
 MODULUS OF TORSIONAL ELASTICITY 10,000,000
 ENDS FINISHED 1- END SQUARE & GROUND
 1- END HOOKED (ONE HALF COIL SQUARE)

PART NO. B9-49-2103

UNLESS OTHERWISE SPECIFIED
 DIMENSIONS ARE IN INCHES.
 TOLERANCES ON FINISHED
 FRACTIONAL DIMENSIONS
 TO BE $\pm 1/32$

- ☒ FINISH AS INDICATED IN MICROINCHES.
- ☐ MACHINE FINISH - ROUGH
- ☐ FLAME CUT OR SAW

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
12-28-55	A	REVISED	JFC	MR.	H.G.
4-17-56	B	TYPE 304 ANNEALED WAS TYPE 302 (MATERIAL SPEC)	JFC	HL	
9-24-59	C	B9-49-2103 WAS B9-13-2008	JFC		
12-11-61	D	ADDED AE-684 TO REF. COL ECD-0374-1	JFC	BP	
2-19-62	E	ADDED SM-TYPE 3 CORE EC 0-357	JFC	JP	EW

ALCO ALCO PRODUCTS, INC. ATOMIC ENERGY DEPT. SCHENECTADY, N. Y., U. S. A.		SCALE	REP. AEL-684	DR.	11-26-55
		FULL SIZE	R9-13-1023	TR.	
MATERIAL SPEC.		18-8 STAINLESS			
		STEEL TYPE 304, ANNEALED			
NAME		SPRING (FUEL ELEMENT)			
PART NO.		B9-49-2103 ©			

DATE	LET	REVISION RECORD	AUTH	DR	CHK
1-5-62	A	① REMOVED: DETAILS OF PCS NO. 1 AND NO. 2; SEPA MODE ② ADDED: REF. TO PCS NO. 1 AND NO. 2 ③ REMOVED: LOW IMPURITY, STAY IT THE 347 ④ TITLE WAS: SM-2 FUEL ELEMENT (CONT. ROD FOR SM-1, SM-1A & PH-2A REACTOR) ECO-0382	JPC	FW	ADP
1-22-62	B	① ADDED NOTE FOR TRUENESS OF HANDLE. ② ADDED FINISHED DIMENSIONS ON HANDLE. ECO-0389	JPC	RDG	FW
2-20-62	C	① SM TYPE 3 CORE AND FUEL ELEMENT FABRICATION SYMBOL TO BE ADDED ECO-0397	JPC	3P	FW

6	1	89-13-2195	COMB.
5	1	A9-13-2077	PIN - HANDLE
4	2	A9-13-2193	HANDLE
3	2	89-13-2194	PLATE EXTENSION
2	2	C9-13-2214	SIDE PLATE
1	16	B9-13-2213	FUEL PLATE
PC. NO.	DRG. NO.	NO. 1	DESCRIPTION
ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.			
SCALE	FULL	DR.	1/12/61
MATERIAL SPEC.	TR.	CHK.	1/23-61
	APP.	1/1/61	2-2-61
	APP.	1/1/61	3-2-61
	MET.	1/1/61	2-4-61
NAME			
FUEL ELEMENT (CONT. ROD)			
PART NO.			
D9-13-1047

PART NO. 39-13-2195

✓	FINISH AS INDICATED IN MICROINCHES.
(f ₁)	MACHINE FINISH - ROUGH
(f ₁₀)	FLAME CUT OR SAW

ALCO PRODUCTS, INC. NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.	
SCALE	2 X SIZE	REF	D9-13-1047
MATERIAL SPEC.		DR.	J. L. Bays 1/20/61
SEE FUEL ELEMENT SPEC.		TR.	
		CHK.	Decker 1-23-61
		APPR.	H. L. Anderson 2-2-61
		APPR.	R. C. Thurman
		MET.	E. L. Egan 2-4-61
NAME		COMB	
CONTROL ROD FUEL ELEMENT			
PART NO.		B9-13-2195	

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
2-19-62	A	MAT'L SPEC. WAS "LOW IMPURITY STN. STL TP 347"			
		"SM TYPE 3 CORE ADDED"	ECO 0397 JTC	J.P. EW	

$\frac{7}{8}$ DIA. (2-HOLES)

125/ ALL OVER

SM TYPE 3 CORE

PART NO.
B9-13-2194

BREAK SHARP EDGES
REMOVE ALL BURRS

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

- ✓ FINISH AS INDICATED
IN MICROINCHES.
- (f1) MACHINE FINISH - ROUGH
- (f10) FLAME CUT OR SAW

		ALCO PRODUCTS, INC.	
		NUCLEAR POWER ENGINEERING DEPT. SCHENECTADY, N. Y., U. S. A.	
SCALE 2" X SIZE	REF. D9-13-1047	DR.	J. L. Boyd 1/13/61
MATERIAL SPEC.		TR.	
SEE FUEL ELEMENT SPEC.		CHK.	Dachon 1-23-61
		APPR.	J. L. Boyd 2-2-61
		APPR.	P. C. Chittum 2-2-61
		MET.	E. C. Chittum 2-4-61
NAME PLATE EXTENSION			
CONTROL ROD FUEL ELEMENT			
PART NO. B9-13-2194			

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
1-16-62	A	ADDED "STAMP" NOTE & (CONTROL ROD) IN TITLE	FCO 0385	JFC.	RDB CGD
		.050 MIN. DIM.			
2-19-62	B	"SM TYPE 3 CORE" ADDED	FCO 0387	JFC.	JPEW

SECTION A-A
SCALE 8 TO 1

SM TYPE 3 CORE

PART NO.
B9-13-2213

BREAK SHARP EDGES
REMOVE ALL BURRS

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

- ✓ FINISH AS INDICATED
IN MICROINCHES.
- ✓1 MACHINE FINISH - ROUGH
- ✓10 FLAME CUT OR SAW

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPT.
SCHENECTADY, N. Y., U. S. A.

SCALE FULL	REF. D9-13-1047	DR.	E.H.W.	1-4-62
MATERIAL SPEC.		TR.		
SEE FUEL ELEMENT SPEC.		CHK.	Duckles	1-8-62
		APPR.	J. Connelly	1-9-62
		APPR.		
		MET.	E.C. Edgar	1-9-62

NAME
FUEL PLATE
(CONTROL ROD)

PART NO.
B9-13-2213

SM TYPE 3 CORE

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
1-16-62	A	ADDED REF. (29-13-1047)	ECO		
		ADDED (CONTROL ROD)	0385		
		TO TITLE	JFC		
1-9-62	B	"SM TYPE 3 CORE" ADDED	JFC		
			JFC		

PART NO.
C9-13-2214

BREAK SHARP EDGES
REMOVE ALL BURS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE ± 1/16

✓ FINISH AS INDICATED
IN MICROFINISH.
① MACHINE FINISH - ROUGH
①/10 FLAME CUT OR SAW

ALCO		ALCO PRODUCTS, INC.	
		NUCLEAR POWER ENGINEERING DEPT. SCHEMECTADY, N. Y., U. S. A.	
SCALE 1:1 & 2:1	DATE 29-13-1047	DR.	E.H.W. 1-5-62
MATERIAL SPEC.		CHK.	D. J. 1-8-62
SEE FUEL ELEMENT SPEC.		APPR.	J. H. 1-9-62
		WRT.	E.C. 1-9-62
NAME SIDE PLATE (CONTROL ROD)		PART NO. C9-13-2214	

PART NO.

A9-13-2193

NOTE: $\sqrt[125]{}$ ALL OVER

BREAK SHARP EDGES
REMOVE ALL BURRS

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

- $\sqrt$ FINISH AS INDICATED
IN MICROINCHES.
- (f1) MACHINE FINISH - ROUGH
- (f10) FLAME CUT OR SAW

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
1-4-62	A	ADDED DIMS. ECO-0382	J.P.C.	E.W.	C.G.D.
1-16-62	B	"V" HOLE WAS $\frac{13}{32}$ DIA. ECO-0385	J.P.C.	R.D.B.	C.G.D.
2-19-62	C	SM TYPE 3 CORE ADDED MATERIAL SPEC WAS: LOW IMPURITY STN STEEL TYPE 347 ECO-0397	J.P.C.	J.P.	E.W.

SM TYPE 3 CORE

ALCO

ALCO PRODUCTS, INC.
NUCLEAR POWER ENGINEERING DEPT.
SCHENECTADY, N. Y., U. S. A.

SCALE FULL	REF. 09-13-1047	DR.	J. L. Boyd	1/13/61
MATERIAL SPEC.		TR.		
SEE FUEL ELEMENT SPEC.		CHK.	D. J. Boyl	1-23-61
		APPR.	J. L. Boyd	2-2-61
		APPR.	R. Chittum	2-2-61
		MET.	E. C. Edger	2-3-61

NAME
HANDLE
CONTROL ROD FUEL ELEMENT

PART NO.

A9-13-2193

PART NO.

A9-13-2077

DATE	LET.	REVISION RECORD	AUTH.	DR.	CHK.
8-15-60	B	RE-DRAWN ^{ECO} 0213	<i>Handwritten signature</i>	R.L.	CGO
		TYPE 304L DELETED FROM MAT. SPEC			
2-19-62	C	"SM TYPE 3 CORE" ADDED MAT'L SPEC WAS: STAINLESS STEEL MAT'L AS USED IN CORE. ECO-6397	JTC	JP	EW

125 ✓ ALL OVER

SM TYPE 3 CORE

BREAK SHARP EDGES
REMOVE ALL BURRSUNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES.
TOLERANCES ON FINISHED
FRACTIONAL DIMENSIONS
TO BE $\pm \frac{1}{64}$ ✓ FINISH AS INDICATED
IN MICROINCHES.f₁ MACHINE FINISH - ROUGHf₁₀ FLAME CUT OR SAW

ALCO

ALCO PRODUCTS, INC.

NUCLEAR POWER ENGINEERING DEPT.
SCHENECTADY, N. Y., U. S. A.

SCALE 12" = 1 FT.	REF. D9-13-101C	DR.	<i>R. Draffen</i>	12-11-56
MATERIAL SPEC.		TR.		
SEE FUEL ELEMENT SPEC.		CHK.	<i>W.H. Pettit</i>	DEC. 13, 56
		APPR.	<i>J. Connolly</i>	2/22/62
		APPR.	<i>Tully</i>	12-13-56
		MET.	<i>ROR</i>	12-13-56

NAME

PIN, HANDLE- FUEL ELEMENT
CONTROL ROD.

PART NO.

A9-13-2077