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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

TITLE

SPECIFICATIONS

LABORATORY HOT PRESS PROCESS
FOR "C" SIZE I & E FUEL ELEMENTS

AUTHOR

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REACTOR AND FUELS RESEARCH
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SPECIFICATIONS
LABORATORY HOT PRESS PROCESS
FOR "C" SIZE I & E FUEL ELEMENTS

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ABSTRACT

Hot press canning of internally and externally cooled fuel elements has been developed to a point where the process is feasible. Complete specifications have been written for the process covering components, dies and punches, furnace construction, nickel plating, component cleaning, component assembly, sizing, hot pressing and inspection. Drawings covering each major item are included.

INTRODUCTION

Hot press canning at Hanford has been developed to a feasible process. Complete conversion of the present production reactors to the use of hot press canned fuel elements would result in an annual net gain of \$3,000,000.⁽¹⁾ This gain results from an increased plutonium production due to the larger diameter of the hot press core. The hot press and nickel plating processes have been described in detail in a number of reports.^{(2),(3),(4),(5),(6)} A consolidation of these reports is presented in this document, in specification form, along with detailed drawings covering each major item. No attempt was made to restrict the furnace or nickel plating facility design, but rather to present these in general terms so as to allow the maximum flexibility in any future design. This specification has been prepared as an aid for production scoping and a guide in production of this type of fuel element. The process described herein is not necessarily the most economical method from a production viewpoint, but rather a method by which consistently acceptable fuel elements can be produced. As this process is a laboratory development, it is probable that many process improvements could be made, especially by the use of automatic equipment. A similar specification has been prepared by Sylvania Electric Products covering the production of the Mark VII fuel element.⁽⁷⁾

- (1) Blanton, W. A., "A Study of Potential Incentives for the Hot Press Process," HW-56822, July 18, 1958.
- (2) Andelin, R. L., "Nickel Plating of Uranium," HW-30243, December 9, 1953.
- (3) Post, R. G. and Kerr, W. B., "Semi-Production Nickel Plating of Fuel Elements," HW-35609, July 11, 1955.
- (4) Foust, W. E., "Hot Press Canning at Hanford," HW-48329, February 11, 1957.
- (5) Tverberg, J. C., "Improvements in the Hot Press Process," HW-59129, April 1, 1959.
- (6) Tverberg, J. C. and Allison, G. S., "Fabrication of Segmented Fuel Elements by Hot Pressing," HW-59130, April 15, 1959.
- (7) Sylvania Electric Products, Inc., "Canning Specifications for Mark VII Fuel Elements," TID-5452, May 14, 1956.

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SUMMARY

Complete specifications are presented covering punch and die design, can, core and cap tube design, cleaning and electroplating of the core, cleaning the can and cap tube, core assembly, hot pressing, inspection and preparation for irradiation. Complete details are also included for the punches, components, dies, plating rack and tru-lining features. Production flowsheets are presented covering each major phase of the operation.

PROCESS SPECIFICATIONS

1.0 Uranium Core (Figure 1)

- 1.1 Standard hot press cores are made from normal uranium with an isotopic content of 0.71 w/o U^{235} .
- 1.2 Each core shall be beta heat treated to assure random orientation and small grain size.
- 1.3 Cores shall be machined according to General Electric Company Drawing H-3-8800. The core model number is C-110-HP-I-S-N.
- 1.4 All surfaces shall have a maximum roughness of 63 micro inches.
- 1.5 Core ID shall pass a 0.434 inch diameter full length mandrel, but a 0.440 inch diameter mandrel shall not enter.
- 1.6 The core ID shall be concentric with the OD within 0.003 inch, total indicator reading.
- 1.7 The following impurities, maximum, can be tolerated.

1.7.1 Determined by chemical analysis.

- 1.7.1.1 Carbon 600 ppm.
- 1.7.1.2 Nitrogen 100 ppm.
- 1.7.1.3 Hydrogen 2 ppm.

1.7.2 Determined by spectrographic analysis.

- 1.7.2.1 Boron 0.2 ppm.
- 1.7.2.2 Cadmium 0.2 ppm.
- 1.7.2.3 Chromium 10 ppm.
- 1.7.2.4 Iron 100 ppm.
- 1.7.2.5 Magnesium 10 ppm.
- 1.7.2.6 Manganese 15 ppm.
- 1.7.2.7 Nickel 30 ppm.
- 1.7.2.8 Silicon Dioxide 50 ppm.

1.8 Minimum core density shall be 18.85 gm/cc.

2.0 Aluminum Can (Figure 2)

- 2.1 Standard hot press cans are made of C-64 aluminum alloy.
- 2.2 Composition of this aluminum alloy is as follows:

- 2.2.1 Aluminum 99.30-99.80 per cent.
- 2.2.2 Iron 0.45 per cent minimum to 0.70 per cent maximum.
- 2.2.3 Silicon 0.17 per cent or less.

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- 2.2.4 Maximum titanium content shall be 0.05 per cent.
 - 2.2.5 Copper content shall be 0.04 per cent, maximum.
 - 2.2.6 Manganese, chromium and zinc shall be 0.03 per cent maximum, each
 - 2.2.7 Maximum magnesium, tin, lead, bismuth and nickel contents shall be 0.01 per cent each.
 - 2.2.8 Lithium content shall be 0.008 per cent, maximum.
 - 2.2.9 Maximum cadmium content shall be 0.003 per cent.
 - 2.2.10 Cobalt and boron contents shall be 0.001 per cent maximum, each.
- 2.3 The cans shall be made according to General Electric Company Drawing Number H-3-8477, Revision one, dated June 10, 1957.
 - 2.4 Outside wall surface scratches shall not exceed 0.003 inch in depth. The surface shall be free of galled and checked areas. Inside surfaces shall be as fabricated and shall be free of stains and defects. Scratches and die marks which do not exceed 0.002 inch in depth shall be permitted.
 - 2.5 All cans shall pass a 1.412 inch diameter full length mandrel and a 1.499 inch diameter full length tube gage.
 - 2.6 Inside base of the can shall be flat.
 - 2.7 The 1.490, 1.474, 0.870, 0.844 and the 0.438 inch diameter surfaces shall be concentric to within 0.003 inch total indicator reading. The 1.490 and 1.420 inch diameter surfaces shall be concentric to within 0.010 inch total indicator reading.
 - 2.8 Surface roughness of the 0.438 inch diameter surface shall not exceed 63 micro inches.
 - 2.9 The 45° bevel on the 1.474 inch diameter can base is optional. This corner may be beveled, square, or rounded.

3.0 Aluminum Cap Tube (Figure 3)

- 3.1 Cap tubes shall be made of C-64 aluminum alloy within the composition limits listed in section 2.2 of this specification.
- 3.2 The cap tube shall be made according to General Electric Company Drawing Number H-3-8478, Revision one, dated June 10, 1957.
- 3.3 Outside wall surface scratches shall not exceed 0.003 inch in depth. The surface shall be free of stained, galled, or checked areas. Inside tube scratches shall not exceed 0.003 inch in depth and the surface shall be free of galled and checked areas.
- 3.4 All cap tubes must pass a 0.348 inch diameter full length mandrel.
- 3.5 The 1.410, 0.375, and 0.427 inch diameter surfaces shall be concentric to within 0.003 inches total indicator reading. The 1.410 and 1.125 inch diameter surfaces shall be concentric to within 0.010 total indicator reading.
- 3.6 Maximum surface roughness of the 1.410 inch diameter surface shall be 63 micro inches. This surface shall be machined to bright parent metal.

4.0 Furnace Construction Details

A single unit furnace is illustrated in Figure 4. In this illustration the circled numbers represent the following items: 1. Die Block; 2. Die Insert; 3. Aluminum Can; 4. Uranium Core; 5. Aluminum Cap Tube; 6. Insulation; 7. Thermocouple; 8. Outer Base Punch; 9. Inner Base Punch; 10. Heating Element; 11. Outer Cap Punch; 12. Pin; 13. Inner Cap Punch; 14. Flash Ring; 15. Heating Element Clamps; and 16. Heater Block.

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4.1 Die Block

- 4.1.1 Construction shall be of "Inconel-X" or other high temperature-high strength material to provide strength at operating temperatures of 650 C and pressures up to 15 tons per square inch.
- 4.1.2 The interior of the die block shall be machined to match the solid die insert (See Section 6.0, Figure 5). The taper of this hole shall be one inch per foot for an approximate included angle of 4°46'16". Also, the die insert and die block shall mate with 90 per cent contact as determined by standard blueing methods.
- 4.1.3 Heating elements should not be placed directly on the die block but rather on a brass or copper heater block for heat distribution properties. Poor heat transfer of the die block will cause burn-out of the elements.

4.2 Heater Block

- 4.2.1 Construction shall be of cartridge brass. The final machined unit shall be nickel plated to provide high temperature oxidation resistance.
- 4.2.2 Heating elements shall be placed in or on this block.

4.3 Heating Elements

- 4.3.1 The type of furnace will determine the choice of heaters. A single unit furnace will require 2,500 watts minimum capacity supplied by calrod heating elements. A four element furnace will require 20,000 watts minimum supplied by cartridge type heating elements.
- 4.3.2 Thin brass sheet (0.010 inches thickness) should be wrapped around the calrod type elements so as to equalize heat flow.

4.4 Insulation

- 4.4.1 Insulation shall be either vermiculite backed by aluminum foil or the fiber type insulators. Powder insulation is not recommended. Block insulation is not recommended due to difficulty of removal during replacement of heating elements.
- 4.4.2 Insulation shall be of sufficient thickness so that there will be no more than a 100 F temperature rise in the furnace shell after 50 hours of continuous operation.

4.5 Instrumentation

4.5.1 Temperature Control

- 4.5.1.1 The instrument may be either a recording or indicating unit of the potentiometer type with proportioning control.
- 4.5.1.2 The instrument shall be able to control to within ± 5 C at 600 Centigrade.

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4.5.2 Overtemperature Control

- 4.5.2.1 The instrument should be of the millivoltmeter type (current meter) and shall operate in the control circuit so as to interrupt the current to the contactor holding coil in the event of a temperature overshoot.
- 4.5.2.2 The overtemperature control shall operate in the 600 C region within ± 10 Centigrade.

4.5.3 Thermocouples

- 4.5.3.1 Thermocouples shall be either chromel-alumel type K or iron-constantan type J, chosen to operate in conjunction with the temperature control instruments.
- 4.5.3.2 The thermocouple well shall extend into the die block. Tight contact of the thermocouple against the well base shall be maintained by a spring loading mechanism.

5.0 Presses

5.1 Press for Hot Pressing

- 5.1.1 Operating capacity shall be a minimum of 20 tons per square inch.
- 5.1.2 Ram speed shall be a minimum of ten inches per minute.
- 5.1.3 Press travel should be a minimum of twelve inches.
- 5.1.4 Pressure indicators may be either electronic or mechanical gages with a range from 0 to 20 tons per square inch.

5.2 Presses for Sizing and Expanding

- 5.2.1 Press type shall be double acting with opposed action rams.
- 5.2.2 Operating capacity shall be a minimum of ten tons.
- 5.2.3 Ram speeds shall be a minimum of ten inches per minute.
- 5.2.4 Press travel shall be a minimum of twelve inches.
- 5.2.5 Pressure indicators shall have a range from 0 to 10 tons.

6.0 Solid Die Insert (Figure 5)

- 6.1 Material for construction shall be any H-21 tool steel such as Formite-2 tool steel (Columbia Tool Steel Corporation) or CLW tool steel (Latrobe Steel Corporation) or equal.
- 6.2 The dies shall be hardened and double drawn at 600 C ± 50 C (1110 F ± 80 F). Rockwell "C" scale hardness shall be 50-55.
- 6.3 Die inserts shall be made according to General Electric Company Drawing Number H-3-8528, dated January 17, 1956.
- 6.4 Exterior taper of the die shall be one inch per foot with an included angle of $4^{\circ}46'16''$. This die shall mate with the die block with 90 per cent contact as determined by standard blueing methods.
- 6.5 Surface finish on the tapered and working surfaces of the die shall be a maximum of 16 micro inches. Maximum roughness of the ends shall be 63 micro inches.

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7.0 Cap Punch (Figure 6)

- 7.1 Material for construction shall be any H-21 tool steel such as Formite-2 tool steel (Columbia Tool Steel Corporation) or equal.
- 7.2 These punches shall be hardened and drawn to 45-55 Rockwell "C" scale and ground to final dimensions.
- 7.3 Maximum surface roughness shall be 16 micro inches except where noted.
- 7.4 Cap punches shall be made according to General Electric Company Drawing Number H-3-8539, Type 1, dated February 11, 1956.

8.0 Base Punch (Figure 7)

- 8.1 Material for construction shall be any H-21 tool steel such as Formite-2 tool steel (Columbia Tool Steel Corporation) or equal.
- 8.2 Hardness of punches shall be 45-55 Rockwell "C" scale.
- 8.3 Maximum surface roughness shall be 16 micro inches except where noted.
- 8.4 Base punches shall be made according to General Electric Company Drawing Number H-3-8584 dated September 14, 1956.

9.0 Cap Punch Ring (Flash Ring - Figure 8)

- 9.1 An expendable flash ring shall be used in conjunction with the outer cap punch (Figure 6a).
- 9.2 Material for construction shall be Shelby seamless mechanical steel tubing, cold drawn, C-1015, finish annealed, 1-1/2 inches OD x 16 BWG.
- 9.3 Cap punch rings shall be made according to General Electric Company Drawing Number H-3-8549, Model II, dated February 11, 1956.

10.0 Fuel Element Pin (Figure 9)

- 10.1 Fuel element pins shall be made of any H-21 tool steel such as Formite-2 (Columbia Tool Steel Corporation) or equal.
- 10.2 Pins shall be hardened and drawn to 50-55 Rockwell "C" scale and ground to final size.
- 10.3 Surface finish shall be 16 micro inches or better except where noted.
- 10.4 Pin body shall have a taper of 0.001 inch per inch of length.
- 10.5 The fuel element pin shall be made according to General Electric Company Drawing Number SK-3-7310, dated March 6, 1957.

11.0 Sizing Die (Figure 10)

- 11.1 Material of construction shall be any O-2 tool steel such as Stentor (Carpenter Steel Corporation), Ketos (Crucible Steel Corporation), or equal.
- 11.2 Hardness shall be 60-64 Rockwell "C" scale. The die shall be ground to final size.
- 11.3 Surface finish shall be 16 micro inches or better unless specified otherwise.
- 11.4 Sizing dies shall be made according to General Electric Company Drawing Number H-3-8527, Part 6, dated January 18, 1956.
- 11.5 During the sizing operation this die shall be mounted within a recess placed on ball bearings so as to permit free movement of the die during sizing.

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12.0 Tube Expander (Figure 11)

- 12.1 Material of construction shall be drill rod, hardened and drawn to Rockwell "C" hardness of 45-55.
- 12.2 Surface finish shall be 16 micro inches or better on the working area and 63 micro inches maximum on all other surfaces.
- 12.3 The tube expander shall be made according to General Electric Company Drawing Number H-3-8582, Part 1, dated April 6, 1956.

13.0 Pad Pressure Punch (Figure 12)

- 13.1 The pad pressure punch shall be used to tightly hold together the can, core and cap tube assembly during the sizing operation.
- 13.2 Material of construction shall be mild steel with a surface finish of 63 micro inches or better.
- 13.3 The pad pressure punch shall be made according to General Electric Company Drawing Number SK-3-6823, Part 1, dated April 9, 1956.

14.0 Staking Punch (Figure 13)

- 14.1 The staking punch shall be used to lock the outer base punch in position on the can base.
- 14.2 Material of construction shall be mild steel. No drawing is available on this item.

15.0 Die Seating, Pressing, and Breaking Blocks

No detailed illustration is presented for the block design as the furnace type will dictate the design. A schematic diagram illustrating die seating, pressing and breaking is presented in Figure 14.

- 15.1 These blocks should be made of Carpenter TK (Carpenter Steel Corporation), Formite-2 (Columbia Tool Steel Corporation), Potomac (Allegheny Ludlum) or equal. Blocks should be hardened to a Rockwell "C" scale hardness of 40-55, but do not need to be ground.
- 15.2 Alignment of the pressing, seating, and breaking dies with the die insert is important. Incorrect alignment can cause back extrusion of the can components.

16.0 Uranium Core Inspection

16.1 Dimensional

- 16.1.1 Each core shall pass the dimensional requirements set forth in paragraphs 1.4 and 1.5 of this specification.
- 16.1.2 Core length shall be a maximum of 8.410 inches and a minimum of 8.390 inches.

- 16.2 The cores shall weigh 8.06 pounds, $\pm$ 0.01 pound.
- 16.3 Each core shall pass the standard transformation test.
- 16.4 Statistical Inspection

- 16.4.1 Random grain orientation shall be verified by x-ray analysis.

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- 16.4.2 High quality of metal shall be verified by metallographic analysis.
- 16.4.3 Chemical purity shall be verified by chemical and spectrographic analysis.

- 16.5 Each core shall be inspected after etching for four minutes in hot (80 C) 50% nitric acid. Any cores indicating inclusions or stringers shall be rejected.
- 16.6 Each core shall be inspected after nickel plating. Any imperfections in the plate or core will be cause for rejection.
- 16.7 Maximum allowable time between plating and pressing shall be eight hours in air. By storing in a vacuum of 10^{-3} mm of mercury this time limit may be extended to twenty hours.

17.0 Aluminum Can Inspection

- 17.1 All aluminum cans shall pass the inspection requirements outlined in Section 2 of this specification. This inspection shall include the following:
 - 17.1.1 Warp.
 - 17.1.2 Concentricity.
 - 17.1.3 Wall thickness.
 - 17.1.4 Base tolerances.
- 17.2 All cans shall pass the quality tests outlined in paragraphs 2.1, 2.3, and 2.7 of this specification. In addition this quality check shall include the following:
 - 17.2.1 Inclusions or defects.
 - 17.2.2 Surface depressions or marks.
 - 17.2.3 Finish.
 - 17.2.4 Material composition.

18.0 Aluminum Cap Tubes

- 18.1 All aluminum cap tubes shall pass the inspection requirements set forth in Section 3 of this specification. This inspection shall include the following:
 - 18.1.1 Warp.
 - 18.1.2 Concentricity.
 - 18.1.3 Wall thickness.
 - 18.1.4 Base tolerances.
- 18.2 All cap tubes shall pass the quality tests outlined in paragraphs 3.1, 3.3, 3.6 of this specification. In addition this quality check shall include the following:
 - 18.2.1 Inclusions or defects.
 - 18.2.2 Surface depressions or marks.
 - 18.2.3 Finish.
 - 18.2.4 Material composition.

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19.0 Vacuum Outgassing

Each core shall be outgassed for a minimum of two hours at 600 C at a maximum pressure of 1×10^{-3} mm of mercury. Not more than twenty days shall lapse between outgassing and processing.

20.0 Nickel Plating of the Uranium Core

20.1 Plating racks (Figure 15)

- 20.1.1 The dual core plating racks shall be made according to General Electric Company Drawing Number H-3-8852.
- 20.1.2 Material of construction shall be 70-30 (cartridge) soft annealed brass except for the stainless steel contact points (15-6), stainless steel screws (15-11), ceramic standoff insulators (15-12) and the platinum electrodes (not shown).
- 20.1.3 The platinum alloy electrode (anode) shall be 18 gage wire twenty inches in length. The platinum alloy shall have the composition of 30 per cent of gold and 70 per cent of platinum.
- 20.1.4 All joints shall be brazed or silver soldered.
- 20.1.5 All surfaces shall be coated with "Unichrome 218X" (United Chromium Corporation) except for contact points and frame contacts (Section "A-A", Figure 15-2).
- 20.1.6 A number 14 insulated stranded copper wire shall be fastened to screw 10, Figure 15, and arranged along the frame before Unichrome 218X application.
- 20.1.7 Current from the plating rack shall pass through a contact point on the frame (Section "A-A", Figure 15-2) to the bus bar. Current shall enter the platinum anode through a clip attached to the anode from the anode bar.

20.2 Equipment

20.2.1 Nickel plating tank

- 20.2.1.1 A suggested size is 48 inches in length, 20-1/2 inches in depth and 20 inches in width. Construction shall be of sheet metal suitably reinforced and protected from corrosion by a heavy coating of Unichrome 218X.
- 20.2.1.2 Commercial plating tanks made of boiler plate with bonded Neoprene or natural rubber are satisfactory.

20.2.2 Plating rack agitator

- 20.2.2.1 The reciprocating motion of the cathode bar shall be supplied by an agitator.
- 20.2.2.2 Stroke shall be a minimum of four inches at a speed of 34 strokes per minute.
- 20.2.2.3 Drive mechanism and tank shall be insulated from the cathode bar by means of plastic roller or bearings.

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20.2.3 Cathode bar

- 20.2.3.1 Cathode bar shall be made of stainless steel to minimize corrosion and facilitate cleaning.
- 20.2.3.2 For a tank 48 inches long, a cathode bar one inch square with a truss super structure will allow support of 75 to 100 pounds without excessive deflection.

20.2.4 Anodes

- 20.2.4.1 Anodes shall be rolled, depolarized nickel metal bars, oval shaped with an anode hook screwed into the anode. These anodes should be approximately three inches in the greater dimension by 1-1/2 inches thick and should extend two inches above the plating solution and within two inches of the tank bottom.
- 20.2.4.2 The anodes shall be spaced as close as possible along the anode bar and three inches from the tank wall.
- 20.2.4.3 Each anode shall be enclosed within a closely woven nylon or glass cloth anode bag. This bag will retain the sludge sloughed off the anode.

20.2.5 Direct current source

- 20.2.5.1 Direct current shall be supplied from a rectifier with a minimum capacity of 200 amperes in the 0-8 volt range. This current shall be controllable in a range of ± 3 per cent.
- 20.2.5.2 Direct current ripple shall not exceed five per cent.

20.2.6 Filters

- 20.2.6.1 The nickel plating solution shall be equipped with a continuous filter to remove suspended particles and provide agitation to minimize temperature gradients.
- 20.2.6.2 Solutions shall be pumped from a manifold on one side of the tank, through a pH cell, into the pump, through the filter and returned to the tank.
- 20.2.6.3 Complete filtration shall occur every 1/2 hour for a tank of the type described in paragraph 20.2.1 of this specification.

20.2.7 Heaters and temperature control

- 20.2.7.1 Immersion type heaters are recommended. These heaters should be placed in a stainless steel sheath, coated with Unichrome 218X compound.
- 20.2.7.2 Temperature control should be from a resistance bulb thermometer operating through a temperature controller. Accuracy shall be ± 0.5 C in the range of 30 to 70 C.

20.2.8 Deionized water

- 20.2.8.1 Deionized water shall be available in sufficient quantity to provide an abundance of water for solution make up, rinsing, etc.
- 20.2.8.2 A minimum capacity of 150 gallons per hour is recommended for the system described in this specification.

20.3 Solution Make-up

20.3.1 Electrolytic etch solution (Light etch)

Orthophosphoric Acid (H_3PO_4) 5.4 M.
Hydrochloric Acid (HCl) 0.12 M.

20.3.2 Nickel plating solution

20.3.2.1 Composition

$NI SO_4 \cdot 6H_2O$	0.426 M
$(NH_4)_2SO_4$	0.159 M
KCl	0.107 M
pH	5.4-5.6

20.3.2.2 Reagent or C. P. Grade chemicals and deionized water shall be used to make the plating solutions.

20.3.2.3 Chemical purification shall be by the method recommended by International Nickel Corporation.

20.3.2.3.1 Adjust pH to 4.5 by addition of ammonium hydroxide.

20.3.2.3.2 Add iron as 0.75 grams of ferrous sulfate per liter, then add 0.8 ml of hydrogen peroxide per liter to oxidize the iron to the ferric state.

20.3.2.3.3 Digest with agitation for 16 hours at 50 C.

20.3.2.3.4 Allow solution to settle for one hour.

20.3.2.3.5 Filter into clean container.

20.3.2.3.6 Add charcoal (12 grams per liter) and agitate at room temperature for two hours.

20.3.2.3.7 Allow to settle for two hours, then filter.

20.3.2.3.8 This purification will remove Fe (II), Fe (III), Cu (II), Zn (II), Cr (III), Al (III). The charcoal will also remove organic impurities such as oil, fatty acids, etc.. Lead ion must be removed by electrolytic purification.

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20.3.2.4 Electrolytic purification

- 20.3.2.4.1 A corrugated rack of the type illustrated in Figure 16 shall be used.
- 20.3.2.4.2 A current density of two amperes per square foot will remove copper, lead and peroxide. A density of five amperes per square foot will effectively remove iron and zinc.

20.3.2.5 Anti-pitting agent

- 20.3.2.5.1 Hydrogen peroxide shall be added as a prevention to gas pitting.
- 20.3.2.5.2 Approximately 0.5 cc per liter of 30 per cent hydrogen peroxide will be required, however, this must be determined for each case.

20.3.2.6 Hydrogen ion concentration (pH = 5.4-5.6)

- 20.3.2.6.1 The pH shall be decreased with a mixture of hydrochloric and sulfuric acid in the same proportion as the plating bath. This ratio is 15 grams of sulfate ion per liter to one gram of chloride ion per liter.
- 20.3.2.6.2 The pH shall be increased to the correct value by adding ammonium ion.
- 20.3.2.6.3 In the event that an inert anode is used which decreases the nickel concentration of the bath, the nickel concentration shall be adjusted by the addition of nickel hydroxide.

20.3.2.7 Chemical analysis shall be made once a month, and the following limits must be maintained:

Ni ⁺⁺	25 g/l	0.426 M	± 0.021 M	
NH ₄ ⁺	5.74 g/l	0.319 M	+ 0.080 M	-0.200 M
K ⁺	4.19 g/l	0.107 M	+ 0.107 M	-0.054 M
SO ₄ ⁼	57.25 g/l	0.585 M	± 0.009 M	
Cl ⁻	3.81 g/l	0.107 M	± 0.011 M	0.029 M

Typical error
as per J.C.T.

20.3.3 Nitric acid baths

- 20.3.3.1 Nitric acid baths shall be used as a deoxidizer and for electrolytic etch coat removal.
- 20.3.3.2 Composition of these baths shall be 10 M nitric acid.

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20.4 Plating process specifications (Figure 17)

20.4.1 Vapor degrease.

- 20.4.1.1 This shall be done in Trichloroethylene vapors heated by steam coils. The top of the tanks shall be cooled to prevent release of trichloroethylene vapors into the room.
- 20.4.1.2 Time in the degreaser shall be sufficient to raise the core temperature to 35 to 40 C. Three minutes shall be the minimum time.

- 20.4.2 Place degreased cores on the plating rack to eliminate further handling of the uranium.
- 20.4.3 Place the racked elements in the nitric acid deoxidizer held at 60 to 65 C for approximately three minutes or until all black oxide film is removed. Time in the nitric acid will vary from 1/2 to three minutes depending on the bath temperature.
- 20.4.4 Thoroughly rinse in tap or process water to remove all traces of nitric acid.
- 20.4.5 Electrolytically etch at a current density of 45 amperes per square foot with the bath at 40 C for four minutes.
- 20.4.6 Thoroughly rinse in tap or process water.
- 20.4.7 Remove anodic film by immersion in warm (30 to 35 C) nitric acid for three to five minutes.
- 20.4.8 Thoroughly rinse in tap or process water.
- 20.4.9 Spray rinse in deionized water.
- 20.4.10 Immerse in the nickel plating bath at 45 amperes per square foot for 26 minutes with a bath temperature of 50 C. This will deposit 0.0008 inch of nickel on the core.
- 20.4.11 Remove from bath and dip rinse in tap or process water.
- 20.4.12 Spray rinse in deionized water.
- 20.4.13 Dip rinse in hot (80 to 95 C) deionized water.
- 20.4.14 Air dry.
- 20.4.15 Wrap in parchment. Any subsequent handling of the cores shall be with degreased cotton gloves or with tongs.
- 20.4.16 Deliver to hot press operation.

21.0 Aluminum Component Preparation (Figure 18)

21.1 Inspected aluminum components shall be subjected to the following cleaning treatment.

- 21.1.1 Scrub with Bab-O Cleanser (B. T. Babbitt, Inc.) two to three minutes or until a matte finish appears.
- 21.1.2 Rinse thoroughly in hot (60 - 80 C) running tap water.
- 21.1.3 Etch in five per cent sodium hydroxide solution at 50 to 60 C for two minutes.
- 21.1.4 Thoroughly rinse in hot (60 to 80 C) running process water for 30 to 45 seconds.

- 21.1.5 Deoxidize with Diversey 514 (Diversey Corporation) for 30 to 60 minutes. Concentration shall be one pound of Diversey per gallon of water at 20 to 30 C. All bonding surfaces must be exposed to this solution.
- 21.1.6 Thoroughly rinse in hot (80 to 95 C) running water for 30 to 45 seconds.
- 21.1.7 Completely dry in air with acetone.

22.0 Pressing Component Preparation

- 22.1 Oxidize any new punches or components in an open air furnace at 450 C for six hours, then air cool.
- 22.2 Spray coat surface of each fuel element pin with a mixture consisting of the following:

31% Clear Lacquer
58% Lacquer Thinner
7% Molykote (Alpha Corporation)
4% Mica (-100-mesh)

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Pins must be sprayed after each pressing cycle.

- 22.3 Coat die inserts with Alemite 40 % (Stewart Warner Corporation) and place in open air furnace at 600 C for a minimum of twenty minutes prior to component assembly.

23.0 Assembly (Figure 19)

- 23.1 No contamination of the bonding surfaces can be tolerated.
- 23.2 Place nickel plated core on clean paper towel with the end with the rounded outside edge up. Take care not to touch surfaces.
- 23.3 Place previously cleaned and completely dried can over the nickel core.
- 23.4 Turn can and core over and insert cap tube into ID of core. Do not handle the cap tube with bare fingers. Use tongs.
- 23.5 Coat OD of can and ID of cap tube with Johnson's #150 Drawing Wax (S. C. Johnson and Son, Inc.) and dry.

24.0 Sizing (Figure 20)

- 24.1 Place fuel element in sizing press.
- 24.2 Apply pad pressure of 500 psi.
- 24.3 Push element through 1.476 inch diameter die for air removal. Release pad pressure and remove element from press.
- 24.4 Place element in expansion press and place 0.376 inch diameter expander into ID of cap tube and attach to press ram.
- 24.5 Apply 500 psi pad pressure.
- 24.6 Pull expander through tube.
- 24.7 Release pad pressure and remove from press.
- 24.8 Trim excess aluminum metal from the can top and cap tube base in a lathe.

25.0 Assembly for Pressing (Figure 20)

- 25.1 Place outer base punch on can base and secure in position by means of staking punch.

- 25.2 Place inner base punch over the coated fuel element pin.
- 25.3 Insert pin into fuel element core and drive into position so that the inner base punch is in contact with can base and the pin is inserted into the punch as far as possible.
- 25.4 Place inner cap punch into position inside the cap tube over the pin.
- 25.5 Coat outside of can with anti-seize compound, consisting of a mixture of water, drawing wax and pulverized (-100-mesh) mica. Allow to dry completely.
- 25.6 Insert coated fuel element into preheated die insert.
- 25.7 Time limit between 21.0, Aluminum Component Preparation, and insertion into the preheated die inserts shall be 90 minutes maximum.
- 25.8 Place flash ring in position.
- 25.9 Place outer cap punch in position.

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26.0 Hot Pressing (Figures 20 and 21)

- 26.1 Place hot inserts with fuel element assembly into the hot die block. Start timing.
- 26.2 Seat die at 1200 psi. This value will vary with die design and will depend upon the amount of prestressing necessary for the insert.
- 26.3 Place pressing blocks in position.
- 26.4 Allow three minutes to lapse between 26.1 and pressing.
- 26.5 Press elements at 600 C (± 5 C) for five minutes (± 10 seconds) at a pressure of 12 tons per square inch (± 500 psi).
- 26.6 Place breaking blocks in position and break die insert from die block.
- 26.7 Quench in 20 C (± 5 C) water.

27.0 Die Disassembly

- 27.1 Remove element from die insert. The element should fall out with a slight tapping action.
- 27.2 Drive out pin.
- 27.3 Remove cap punches as a unit. These punches will be held together by aluminum flash.
- 27.4 Remove flash ring and throw away.
- 27.5 Remove base punch as a unit. Again, these are held together by aluminum flash.

28.0 Punch, Pin and Die Recycling

- 28.1 Separate inner from outer punches by pressing.
- 28.2 Place punches in 5 per cent solution of sodium hydroxide to dissolve the aluminum flash. Rinse and dry.
- 28.3 Re-spray pins by method described in paragraph 22.2 of this specification.
- 28.4 Recoat die insert with Alemite 40 % and replace in preheated furnace at 600 C.

29.0 Fuel Element Final Preparation

- 29.1 Clean elements in hot (80 C) 50 per cent nitric acid. Remove all surface imbedded particles.
- 29.2 Machine "TRU-LINE" feature as illustrated in Figure 22. Minimum cap and base thickness shall be 0.25 inches. Remove 0.045 inch ± 0.005 , then contour as in General Electric Company Drawing Number H-3-8479.

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30.0 Inspection

30.1 Dimensional check

- 30.1.1 Outer diameter to be 1.475 minimum, 1.479 inches maximum.
- 30.1.2 Inner diameter to be 0.375 inch $\pm$ 0.0005 tapered to 0.3646 inch $\pm$ 0.0005.
- 30.1.3 Overall length shall be 8.9 inches minimum.
- 30.1.4 Fluoroscopic measurement of cap and base thickness.

30.2 Bond test. The most practical test to date has been the thermoinductive test (Frost Test) in which the element OD is spray coated with a mixture of acetnaphthalene dissolved in chloroform. This is then passed through an induction coil. The element will present a frosted appearance over all bonded surfaces and a smooth greasy appearance over an unbonded surface. Fuel element ID is checked by spray coating paper with acetnaphthalene, then inserting the coated paper into the ID of the element and placing a single turn inductor through the core. Appearance of the paper will be the same as for the outside of the element. Duration of time in the induction coil is dependent on the inductive power.

30.3 Weld test. Either a standard die check method or vacuum bubble chamber with kerosene is sufficient.

30.4 Surface inspection for dents more than 0.003 inches in depth.

31.0 Final Etch

Final etching shall take place in hot (80 C) 50 per cent nitric acid. Etching shall leave a silver matte finish on the elements.

32.0 Autoclaving

32.1 Elements shall be either steam or water autoclaved at 180 C for 20 hours.

32.2 Any elements which show signs of swelling, discoloration, etc., shall be rejected.

33.0 Preirradiation Measurements

Each element shall be measured and arranged according to tube make-up at the time of measurements.

34.0 Irradiation

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FIGURE 1

Uranium Core for Hot Press Process

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FIGURE 2
Aluminum Can

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FIGURE 3
Aluminum Cap Tube

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FIGURE 4

Cross-Sectional View of Single Unit Hot Press
Furnace

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FIGURE 5
Solid Die Insert

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a. Outer Cap Punch

b. Inner Cap Punch

c. Assembled Cap Punch

FIGURE 6

Cap Punch Details

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a. Outer Base Punch

b. Inner Base Punch

FIGURE 7

Base Punch Details

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FIGURE 8
Cap Punch Ring

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FIGURE 9

Fuel Element Pin

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FIGURE 10

Sizing Die

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FIGURE 11
Tube Expander

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Surface Finish $\sqrt{63}$

FIGURE 12
Pad Pressure Punch

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FIGURE 13
Staking Punch

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FIGURE 14

Steps Involved in Hot Pressing the Assembled Core

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FIGURE 15

Plating Rack Details

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FIGURE 16

Corrugated Rack for Low Current-density Purification of Plating Bath.

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FIGURE 17

Nickel Plating Process

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FIGURE 18

Flowsheet for the Cleaning of Aluminum Components for Hot Pressing

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FIGURE 19

Flowsheet for the Assembly of Fuel Element Components for Hot Pressing Operation

FIGURE 20

Flowsheet for Hot Pressing I & E Fuel Elements

FIGURE 21

Action of Single-stroke, Hot Work Punches for Hot-press I & E Elements

a. Fuel Element Base

b. Fuel Element Cap

FIGURE 22

Tru-Lining Feature for Hot Pressed Fuel
Elements

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