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PROVISIONAL SPECIFICATIONS
FOR THE HOT DIE SIZING PROCESS

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PROVISIONAL SPECIFICATIONS
FOR THE HOT DIE SIZING PROCESS

Issued By

Process Development Unit
Fuels Engineering Operation
Production Fuels Section, IPD

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PROVISIONAL SPECIFICATIONS
FOR THE HOT DIE SIZING PROCESS

SYNOPSIS

This document establishes the provisional process specifications for the hot die sizing process. The specifications cover components, dies, nickel plating, component cleaning, assembly preheating, sizing, end bonding, finishing and inspection.

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INTRODUCTION

Hot die sizing is one of three solid state diffusion bonding (SSDB) processes that has been proposed as an alternate manufacturing process for fabricating HAPU metallic uranium, aluminum-clad fuel elements. The incentives and some specifications for these processes (hot press, hot die sizing, fluid pressure bonding) have been detailed in a number of reports. (Ref: 1,2,3,4,5)

This document establishes the provisional process specifications for the assembly of fuel elements by the hot die sizing process. These specifications were developed for the CDB2N model fuel element (C5N equivalent AlSi model) and do not necessarily apply to any other model.

PROCESS SPECIFICATIONS

1.0 Uranium Core

1.1 Core Dimensional Requirements

Basis:

The dimensional characteristics of the HDS uranium fuel core are established by reactor and process requirements. Finished fuel element dimensions and configuration are controlled by reactor requirements. The process establishes the size and configuration of the uranium core that will yield these finished fuel dimensions. One such factor is the thinner bond layer employed in the HDS process

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that results in a larger uranium core than the equivalent AlSi model. There is also an interaction between the core configuration and nickel plating (nickel will tend to build up or "tree" on a sharp corner), and sizing processes (allow for proper metal flow during sizing to obtain a bond).

Specifications:

1.1.1 Cores shall conform with drawing number H-3-17363, Rev. 4, a copy of which is attached as Figure 1.

1.2 Core Metallurgical Requirements (Ref: 7)

Basis:

The metal quality characteristics of uranium fuel cores correspond to those established for the AlSi process, except as noted.

Specifications:

- 1.2.1 The core shall meet the requirements specified in HW-47029, "Process Specifications Fuel Element Manufacturing Processes", November 15, 1962, specification number F101, with the following exceptions:
- a. Specification F101.4: Figure F101-4 replaced by Figure 1 of this specification.
  - b. Specification F101.5A: Inspect after nickel plating rather than nitric acid pickle.
  - c. Specification F101.5B: The requirements of the reprocessing cycle for HDS fuels have not been established.

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- d. Specification F101.7: The requirements of the reprocessing cycle for HDS fuels have not been established.
- e. Specification F101.8: diaphragm valves for HDS fuel have not been established.

2.0 Aluminum Spire-Can and Cap Wafer Components

2.1 Can and Cap Dimensional Requirements

Basis:

The HDS process employs an integral spire-can and a flat cap wafer. Dimensions of these components are governed by the amount of metal upset and sizing required to yield bonded fuel elements of the prescribed dimensions and cladding thickness.

Specifications:

- 2.1.1 The spire-can shall conform with drawing number H-3-17962, Rev. 1, a copy of which is attached as Figure 2.
- 2.1.2 The cap wafer shall conform with drawing number H-3-17364, Rev. 2, a copy of which is attached as Figure 3.

2.2 Can and Cap Metallurgical Requirements

Basis:

Metal quality of can and cap components is the same as for AlSi process components, except as noted.

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Specifications:

- 2.2.1 The spire-can and cap wafer shall be 8001-F aluminum alloy (Ref: HW-47029, "Process Specifications Fuel Element Manufacturing Processes", November 15, 1962, Specifications F105.1 a).
- 2.2.2 The spire-can and cap wafer shall meet the requirements outlined in HW-47029 specification F105 with the following exceptions:
  - a. Specification F105.4, Figure F105-1 replaced by Figure 2 of this specification.
  - b. Specification F105.5, Figure F105-3 replaced by Figure 3 of this specification.

3.0 Aluminum Component Preparation

Basis:

Aluminum components are cleaned and deoxidized to provide a clean bonding surface and to facilitate lubricant application. The presence of extrusion lubricants, stains, heavy oxide films and inclusions on the surface inhibits bonding.

Specifications:

- 3.1 The components shall be etched for a period of time sufficient to remove $0.005 \pm .002$ inches on the can O.D. and $0.008 \pm .002$ inches on the cap O.D.
- 3.2 A maximum of 72 hours may be allowed between cleaning and sizing when the components are stored in a 1000 micron vacuum; 4 hours when stored in air.

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Operating Technique: (Figure 4)

A. Components shall be cleaned and etched according to the following process, allowing no portion of the surface to dry until step 9.

1. Caustic etch:

Solution composition: 4 to 5 oz/gal solution of Aluminux (or equivalent inhibited caustic).

Temperature: 50 to 60 C (122 to 140 F).

Immersion Time: Sufficient to remove amount specified in 3.1 of this specification. This is controlled by a 10% sampling rate.

2. Hot process water rinse:

Rinse by dipping

3. Caustic etch:

Solution composition: 4 to 5 oz/gal solution of Aluminux (or equivalent inhibited caustic).

Temperature: 50 to 60 C (122 to 140 F).

Immersion time: 10 $\pm$ 5 seconds.

4. Hot process water rinse:

Rinse by dipping.

5. Cold process water rinse:

Rinse by dipping.

6. Deoxidize:

Solution composition: 16 $\pm$ 3 oz/gal Diversay 514

Temperature: 10 to 30 C (50 to 86 F)

Immersion Time: 10 to 30 minutes

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7. Cold process water rinse:

Rinse by immersion

Temperature: 30 C (86 F) maximum

Immersion time: 50 seconds minimum

8. Methanol rinse:

Rinse by dipping

Temperature: 18 to 25 C (64 to 76 F)

Specific gravity: .842 maximum

H₂O content: 18% maximum

9. Dry:

Dry in forced warm air

Temperature: 70 C (158 F) maximum

Drying time: 30 minutes maximum

10. Storage:

Store the etched and dried components as outlined
in 3.2 of this specification.

11. Any handling of the cleaned and dried components will
be with clean cotton gloves.

4.0 AlSi Wafers

Basis:

An AlSi wafer is used in the hot die sizing process as an additional corrosion barrier to reactor cooling water entry. The AlSi wafer is placed between each end of the nickel plated uranium core and cladding components.

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Specification:

- 4.1 AlSi wafers shall be stamped from .010 $\pm$ .002 inch thick, 9 to 11% silicon, cold rolled sheetstock.
- 4.2 AlSi wafers shall conform with drawing number H-3-18206, a copy of which is attached as Figure 5.

5.0 AlSi Wafer Preparation

Basis:

The AlSi wafers are cleaned and deoxidized to provide a clean bonding surface for bonding to the aluminum components and nickel plated uranium core.

Specification:

- 5.1 AlSi wafers shall be free of fabricating oils, stains, cracks, and inclusions.

Operating Technique: (Figure 6)

- A. AlSi wafers shall be cleaned as follows, assuring that all surfaces are exposed to cleaning media.

1. Caustic etch:

Solution composition: 2 to 2 oz/gal Turco
4181-19 (or equivalent
detergent caustic)

Temperature: 65 to 70 C (150 to 158 F)

Immersion time: 30 $\pm$ 2 seconds

2. Process water rinse:

3. Caustic etch:

Solution composition: 2 to 3 oz/gal Turco
4181-19 (or equivalent
detergent caustic)

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Temperature: 65 to 70 C (150 to 158 F)

Immersion time: 3 to 5 seconds

4. Process water rinse:

5. Acid etch:

Solution composition: Process Water
HNO₃ 30 ± 1 vol%
HF 0.5 ± 0.1 vol%

Temperature: 65 to 70 C (150 to 158 F)

Immersion time: 2 to 3 minutes

6. Process water rinse

7. Deoxidize:

Solution composition: Process Water
HNO₃ 20 ± 3 vol%

Temperature: 65 to 70 C (150 to 158 F)

Immersion time: 2 minutes ± 5 seconds

8. Process water rinse:

9. Methanol rinse:

Temperature: 18 to 25 C (64 to 76 F)

Specific Gravity: .842 maximum

H₂O Content: 18% maximum

10. Dry:

Forced warm air

Temperature: 70 C (158 F) maximum

Drying Time: 20 minutes maximum

11. Any handling of the cleaned and dried AlSi wafers will be with clean cotton gloves.

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6.0 Nickel Plating of the HDS Uranium Core (Ref: 8)

Basis:

Uranium cores are electro-nickel plated to provide a solid state diffusion bonded barrier between the cores and aluminum cladding components.

The nickel plate also serves as a secondary corrosion barrier in case of water entry through a jacketing defect.

Specification:

- 6.1 Electrodeposit 0.0008 ± 0.0003 inches of nickel on a cleaned and deoxidized uranium fuel core. This plate shall be continuous and free of stains.
- 6.2 Since the quality of the nickel plated uranium core is so critical to the bonding process, an outline of plate quality testing is included in this process specification as Appendix A.
- 6.3 Place the nickel plated cores in a 1000 micron vacuum within 4 hours after removal from the plating bath. The maximum holding period in the vacuum shall be 24 hours.

Operating Technique: (Figure 7)

- A. The uranium cores are positioned on electrical contacts in the nickel plating racks (Figure 8). An inert anode* is

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* Anode rod: #8 Gauge (B&S) X 20-1/2" LG., Gold 30%, Platinum 70%, Heat treated to maximum hardness.

Alternate Anode rod: Platinum plated titanium.

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then positioned through the I.D. of the uranium fuel core to provide a uniform current density. The pretreatment and plating process of the uranium fuel core is as follows:

1. Alkaline clean:

Solution composition: Process Water
NaOH 2.0 to 2.5 M
Duponal 10 to 12 gm/l
Sp. Gr. 1.10 to 1.13 @ 18-22 C
(64 - 72 F)

Temperature: 80 to 90 C (176 to 194 F)

Immersion time: 2 to 3 minutes

2. Cold process water rinse:

Two 15 to 30 second immersions

3. Deoxidize:

Solution composition: Process Water
HNO₃ 7.5 to 10.0 M
Uranium 1.7 M (maximum)

Temperature: 65 to 70 C (149 to 158 F)

Immersion Time: 2 to 5 minutes

4. Cold process water rinse:

Two 15 to 30 second immersions

5. Electrolytic etch:

Solution composition: Deionized Water
H₃PO₄ 5.7 to 6.5 M
HCl .33 to .40 M
Uranium 0.05 to 0.15 M

Temperature: 20 to 30 C (68 to 86 F)

Immersion time: 6 to 6.5 minutes

Current density: 50 to 55 amperes per square foot of uranium surface. The inert anode (Ref: A of this operating technique) is cathodic during electrolytic etch.

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6. Cold process water rinse:

Two minutes (minimum) by immersion

7. Cold process water spray rinse:

To remove gelatinous material from electrolytic
etch process (Ref: Step 5)

Optional: Cold process water rinse by two 15 to
30 second immersions.

8. Deoxidize:

Solution composition: Process Water
HNO₃ 7.5 to 8.0 M
Uranium 0.4 M maximum

Temperature: 38 to 42 C (100 to 108 F)

Immersion time: 5 to 7 minutes

Procedure: Rotate the core on the electri-
cal contacts one half way
through this step in order to
obtain uniform deoxidizing.

9. Cold deionized water rinse:

With a 15 to 30 second immersion in each of three
counter-current rinse tanks. The last two rinses
shall be > 100,000 ohm-cm specific resistance.

Optional: The first rinse may be in process water.

10. Nickel Plating

Solution composition: NiSO₄ 1.1 to 1.3 M
NiCl₂ .12 to .25 M
H₃BO₄ .50 to .75 M
pH . 1.5 to 2.5 @ 50 C
(122 F)

Temperature: 48 to 52 C (118 - 126 F)

Immersion time: 25 ± 2 minutes

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Current density: External surface--50 to 55
amperes/sq. ft.
Internal surface--100-110
amperes/sq. ft.

Procedure: Connect the DC power to the plating rack prior to immersion (core cathodic). Rotate the core on the electrical contacts one half to two minutes after immersion and every 5 to 10 minutes thereafter. The inert anode (Ref:"A" of this operating technique) is anodic during nickel plating.

11. Optional:

Cold process water rinse:

Two 15 to 30 second immersions

12. Cold deionized water rinse:

With a 15 to 30 second immersion in at least two counter-current rinse tanks and a minimum of one minute in the final rinse. Specific resistance shall be $>100,000$ ohm-cm.

13. Hot deionized water rinse:

Temperature: 40 to 60 C (104 to 140 F). One to 1-1/2 minute immersion. Specific resistance shall be $\geq 500,000$ ohm-cm.

14. Dry in forced warm air:

Procedure: Remove the cores from the plating racks with clean paper tissues and dry in forced warm air. If water marks appear, they may be removed by a subsequent rinse in the hot deionized water and drying. Dry core shall be handled only with freshly laundered cotton gloves.

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15. Inspection:

Inspect the entire surface of the core for stains, discontinuities in the plate, nonuniformity of the surface finish and color, and defects in the uranium. (Ref: 1.2.1 of this specification)

16. Storage:

Store the nickel plated uranium core as outlined in 6.3 of this specification.

17. An outline on process control is included as Appendix B of this specification.

7.0 Assembly

Basis:

The integrity of the solid state diffusion bond is dependent on proper assembly and handling.

Specification:

7.1 There shall be no contamination of the bonding surfaces such as stains and fingerprints or particulate material in the can component prior to assembly.

7.2 When the AlSi wafers are used, they shall be placed between the face ends of the nickel plated uranium core and the aluminum components.

Operating Technique: (Figure 9)

A. During assembly, handle all components with clean cotton gloves.

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8.0 Component Dry Film Lubricant

Basis:

The dry film lubricant (Figure 10) is used to facilitate the sizing of the HDS fuel assembly.

Specification:

- 8.1 The dry film lubricant shall be a mixture of four parts, by volume, process water to one part, by volume, Aqua-Dag.
- 8.2 Thorough mixing shall be provided prior to application.
- 8.3 The lubricant film shall be continuous.

Operating Technique:

- A. The dry film lubricant mixture shall be stored in a covered container when not in use.
- B. The can component shall have been previously cleaned according to Section 3 of this specification.

1. Lubrication:

The can component shall be immersed in the lubricant mixture to within 2 to 2-1/2 inches of the top of the can component. If it is necessary to grasp the can component below this 2 to 2-1/2 inches prior to lubrication, use clean cotton gloves.

2. Drying:

Allow the can component to drain and surface dry.

3. Storage:

When surface dry, place in the vacuum dryer.

(Ref: Section 9 of this specification)

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9.0 Vacuum Drying

Basis:

The vacuum dryer (Figure 11) is used to remove any residual moisture from either the uranium core as a result of the nickel plating process or the cleaning of the aluminum components. The vacuum dryer is also used for holding the fuel assembly for longer periods of time between nickel plating and sizing than could be tolerated if stored in air.

Specification:

9.1 The fuel assembly shall be held in a vacuum of 1000 microns, minimum, for at least 30 minutes at 38 ± 5 C (100 ± 10 F) prior to sizing. The maximum holding period in a vacuum between plating and sizing shall be 24 hours; in air 8 hours.

9.2 Backfill the fuel assembly with argon.

Operating Technique:

- A. Place the lubricated fuel assembly (Ref: Section 8 of this specification) in the vacuum dryer in the vertical position.
- B. Prior to removal of the fuel assembly from the vacuum dryer, the chamber containing the fuel assembly shall be backfilled with argon.
- C. Immediately upon removing the fuel element from the vacuum dryer, place it in the pre-heat carrier (Figure 12). Care must be exercised in avoiding any smearing or wiping of the dry film lubricant and to maintain the fuel assembly in the vertical position.

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10.0 Fuel Assembly Pre-Heat

Basis:

The fuel assembly must be pre-heated to a relatively high temperature. It must have sufficient thermal energy to create the solid state diffusion bond in the subsequent sizing operation.

Specification:

10.1 Pre-heat the fuel assembly until the uranium fuel core attains an average "lateral interface" temperature (on the external lateral surface of the core) of 525 to 575 C (977 to 1067 F).

10.2 A maximum of 20 seconds shall be allowed for transfer from preheating to end loading in the sizing press.

Operating Technique:

A. Experience has shown that the uranium fuel core (in the fuel assembly) is preheated to an average "lateral interface" temperature of 525 to 575 C (977 to 1067 F) in 11-1/2 to 14 minutes, respectively at a pre-heat furnace (Figure 13) temperature setting of 680°C (1256°F).

11.0 Hot Die Sizing (Ref: 9)

Basis:

To produce a solid state diffusion bond, the preheated fuel assembly must be subjected to relatively high pressure. This is accomplished in the HDS process by sizing the HDS fuel assembly through an external and over an internal die simultaneously

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(Figures 14 and 15). This momentary application of pressure at an elevated temperature is sufficient to produce a thin yet strong and uniform bond.

Specification:

- 11.1 Size the fuel assembly with a ram speed of 70 ± 10 ipm.
- 11.2 The lower ram force (back pressure) shall be a minimum of 1/4 ton.
- 11.3 The upper sizing ram force shall be the total of the lower ram force and the die resistance forces. Experience has shown this to be approximately 3 tons.
- 11.4 After sizing, air quench the fuel assembly for 20 ± 2 seconds with a stream of compressed air.

Operating Technique: (Figure 9)

- A. In order to control the lower ram back pressure, the viscosity characteristics of the hydraulic fluid used must be known. Experience has shown that the present hydraulic fluid must operate in the 35 to 50 C (95 to 125 F) temperature range in order to control this pressure.
- B. The internal and external sizing dies shall be free of aluminum and foreign material.
- C. The external sizing die shall be heated to a temperature of 65 to 95 C (150 to 200 F) on initial startup of the sizing press.
- D. Freely lubricate the internal and external dies with Fiske 604, a suspension of graphite and aluminum, before

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sizing each fuel assembly. Care must be exercised to make sure that the die land is lubricated. The sizing sequence is as follows:

1. Pre-Heat:

Pre-heat the fuel assembly as outlined in Section 10 of this specification.

2. Alignment:

Place the preheated fuel assembly in the positioner on the sizing press.

Clamp the preheat carrier into position. Alignment of the fuel assembly is critical to the sizing operation. Therefore, alignment shall be maintained until the end loading pressure (created as the upper ram forces the lower ram down under pre-set back pressure) is applied to the fuel assembly.

3. Sizing:

Apply an end-load to the fuel assembly and size as outlined in 11.1, 11.2, and 11.3 of this specification.

4. Forced Air Quench:

Air quench the sized fuel assembly in place below the die as outlined in 11.4 of this specification.

5. Internal Die Removal:

After removing the fuel assembly from the sizing press, recover the internal die with the die remover (Figure 13).

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6. Air Quench:

Allow the fuel assembly to cool to room temperature by exposure to ambient air.

12.0 Lubricant RemovalBasis:

The residual sizing lubricants are removed from the sized fuel assembly at this point for two reasons. First, lubrication of the fuel assembly is not required in any subsequent steps of the process and, secondly, removal of the lubricant provides for cleaner handling techniques.

Specification:

12.1 The fuel assembly shall be cleaned in Stoddard solvent.

Operating Technique:

A. Care must be exercised in preventing possible contamination of the cap-can junction with Stoddard solvent.

13.0 Initial FacingBasis:

The as sized fuel assembly has about 4 inches of aluminum "flash" that extends past the cap wafer. This "flash" must be removed so that the end bonding dies may be placed on the fuel assembly for end bonding.

Specification:

13.1 Trim the aluminum flash off of the cap end of the fuel element.

13.2 Face off a nominal $.010 \pm .005$ from both the cap and base ends.

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14.0 End Bonding

Basis:

During the sizing operation the flat face ends of the fuel assembly are not bonded. Therefore, it is necessary to do this in a separate step. End bonding is accomplished by placing differential thermal expansion dies (Figure 16) on the end of the fuel element and applying a longitudinally compressive load with the fuel element assembly at an elevated temperature.

Specification:

- 14.1 Preheat the fuel assembly, with dies, to an "end interface" temperature (between the end of the uranium core and aluminum jacket) of 375 to 385 C (705 to 725 F). Thermocouple tests show that this is accomplished in 6 minutes $\pm$ 15 seconds @ 680°C (1256°F) in the pre-heat furnace (Figure 13).
- 14.2 Total elapsed transfer time from the furnace to end loading in the end bonding press shall not exceed 25 seconds.
- 14.3 The end loading pressure shall be 4 $\pm$ 1/4 tons per square inch on the end of the fuel element.
- 14.4 The end load shall be applied in the end-bonding press until an "end interface" temperature of 575 to 595 C (1067 to 1103 F) is attained. Using the resistance heater heads this is accomplished in 4-1/2 minutes $\pm$ 15 seconds @ 655°C (1211°F).
- 14.5 Water quench after removal from the end-bonding press.

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Operating Technique: (Figures 9 & 17)

- A. The dies shall be free of aluminum and foreign material.
- B. The fuel element shall be free of sizing lubricants
(Ref: Section 12 of this specification).

1. Assembly:

When assembling the fuel element and dies, make sure the dies are seated against the ends of the fuel elements.

2. Preheat:

The fuel element assembly with dies shall be preheated as outlined in 14.1 of this specification. The assembly shall be supported in the preheat furnace on the die cups.

3. End Bonding:

End bond the fuel element as outlined in 14.3 and 14.4 of this specification.

4. Quench:

Water quench the fuel assembly after removal from the end bonding press.

5. Die Removal:

Remove the internal and external dies from the end bonded fuel element.

15.0 Final Facing

Basis:

The bonded fuel element is faced to provide a clean surface for welding and to assure sufficient cap thickness for adequate

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heat transfer from the face ends of the fuel element during irradiation.

Specification:

15.1 The end contours shall conform to the specifications of Figure 18.

15.2 The residual cap and base thickness shall be a minimum of 0.165 inches.

15.3 The minimum fuel element length shall be 8.930 inches.

Operating Technique:

A. Nominal thickness; cap--0.201; base--0.213 inches.

B. Finished fuel element length; $9.034 + .043$, - .104 inches.

16.0 Welding

Basis:

The closure zone of the faced fuel element is welded to provide a closure of the cap and can interface.

Specifications:

16.1 The weld penetration, measured from the top of the cap to the bottom of the fusion zone shall be 0.050 inches, minimum.

16.2 There shall be a minimum of 0.025 inches cover over the diffusion zone.

Operating Technique:

A. After welding the external closure, the fuel element shall be allowed to cool to room temperature before welding the internal closure.

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1. Weld Current:

External weld: 140 amps, minimum, DC

Internal weld: 125 amps, minimum, DC

2. Turntable Speed:

20 $\pm$ 1 RPM. Double pass plus crater fill.

3. Gas:

95 - 98% helium at a flow rate of 17 to 19 cubic feet per hour.

2 - 5% Argon at a flow rate of 1 to 2 cubic feet per hour.

4. Electrode:

3/32 inch diameter, 2 per cent thoriated tungsten electrode ground to a point.

5. Electrode Gap:

1/32 inch, maximum

6. Electrode Extension:

1/16 maximum with #7 nozzle.

17.0 Testing

17.1 Bond Test

Basis:

The bond test is used to reject those fuel elements which have large unbonded area between the lateral core surface and the cladding. A metallic bond is necessary to assure adequate heat transfer during irradiation.

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Specification:

- 17.1.1 The tester shall be set up according to the standard "F" process (Ref: 6) with the following exception.
- a. The tester shall reject fuel elements that have a total count greater than 75.

17.2 Clad Thickness Test

Basis:

The clad thickness tester is an eddy current tester adapted for use with the HDS fuel elements. This test is used to reject those fuel elements that have clad thinning.

Specification:

- 17.2.1 Finished fuel elements shall have a cladding thickness of not less than 0.025 inches.

17.3 End Bond Test

Basis:

This test is used to reject those fuel elements which have unbonded areas between the face ends of the uranium fuel core and the cladding.

Specification:

- 17.3.1 The End Bond tester shall reject fuel elements that have a total count greater than that obtained from a 1/4 inch diameter unbonded area.

17.4 End Closure Test UT-4

Basis:

The UT-4 tester is used to reject those fuel elements that have voids and/or inclusions at the cap-can interface

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that act as a path for reactor coolant water entry.

Specifications: (Ref: 12)

17.4.1 The test shall conform to temporary specification PWR No. 86, August, 1963, C. J. Denton, with the following exceptions:

- a. The reject point shall be 18 total "discs" or 12 consecutive "discs".

18.0 Fuel Element Etch

Basis:

The etch process removes contaminants from the fuel element surface that may inhibit the formation of a uniform oxide coat during autoclaving and/or cause localized corrosion while in the reactor.

Specifications:

18.1 Not more than 0.002 inch of aluminum shall be removed from the fuel element surface during the etch process.

Operating Technique:

A. The fuel element shall be etched according to the following process, allowing no portion of the surface to dry until step #7.

1. Nitric Etch:

Solution Composition: 55 to 60 wt.% nitric acid

Temperature: 75 - 85 C (166 - 185 F).

Immersion Time: 5 minutes $\pm$ 30 seconds.

2. Process Water Rinse:

Rinse by dipping.

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3. Caustic Etch:

Solution Composition: 2.5 to 3 oz/gal Turco 4181-19
(or equivalent detergent caustic)

Temperature: 80 - 85 C (176 - 185 F)

4. Process Water Rinse:

Rinse by dipping

5. Nitric Etch:

Solution Composition: 15 to 30 wt.% nitric acid

Temperature: 85 $\pm$ 5°C (185 $\pm$ 10°F)

Immersion Time: 12 to 15 minutes

6. Process Water Rinse:

Rinse by dipping

7. Dry:

Forced warm air

Temperature: 40 C (104 F) minimum

19.0 Weld Inspection

Basis:

Weld inspection is used to reject those fuel elements with unsound welds.

Specification:

19.1 The internal and external welds shall be inspected for weld defects in accordance with HW-47029, "Process Specifications Fuel Element Manufacturing Processes", November 15, 1962, specification F405.1 i.

19.2 The internal weld shall pass a mandrel not more than 0.012 inches smaller than the minimum spire I.D. (CDB2N is 0.365).

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19.3 The external weld shall pass a ring gage not more than .010 inches larger than the maximum can O.D. (CDB2N is 1.502).

20.0 Rail Weld

Basis:

The self-support rails are used on the CDB2N model for use in the smooth bore reactor tubes.

Specification:

20.1 Self-support rails shall be ultrasonically welded on the fuel element in accordance with present "F" process (Ref: 10).

21.0 Autoclave

Basis:

The autoclave test is designed to cause failure of fuel elements which have a water entry path through the weld closure or cladding. It causes accelerated corrosion of fuel elements containing corrosive contaminants, thus permitting visual detection of such fuel elements, and it produces a corrosion and mar resistant oxide film.

Specification:

21.1 The fuel element shall be autoclaved according to HW-47029, "Process Specifications Fuel Element Manufacturing Processes, March 15, 1962, specification F404.

22.0 Finished Fuel Element Characteristics

Basis:

Some physical characteristics of the finished fuel element may be cause for failure during reactor exposure.

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Specification:

22.1 The finished fuel element shall conform to HW-47029, "Process Specifications Fuel Element Manufacturing Processes, November 15, 1962, specification F405, with the following exceptions:

- a. Specification F405.1, a3: Change 0.200 inches on base end to 0.115 inches. No weld on base end.
- b. Specification F405.1, a4: No line identification on the HDS fuels.
- c. Specification F405.1, a5: Change 0.175 inches on cap end to 0.095 inches.
- d. Specification F405.1, b: Plate gage setting shall be 1.507 inches.
- e. Specification F405.1, c: Mandrel shall be .360 inches.
- f. Specification F405.1, d: The spire tube shall be included in this specification.
- g. Specification F405.1, f: AlSi surface contamination is not involved in the HDS process.
- h. Specification F405.2: dih values have not been established

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REFERENCES

1. HW-72848, "Technology, Economics and Incentives for a Solid State Diffusion Bonding Process-Hot Die Sizing", C. A. Burgess, March 1, 1962.
2. HW-56822, "Study of Potential Incentives for the Hot Press Process", W. A. Blanton, July 18, 1958.
3. HW-61995, "Specifications--Laboratory Hot Press Process for "C" Size I&E Fuel Elements", J. C. Tverberg, September 25, 1959.
4. HW-73111, "Supplemental Specifications of Laboratory Hot Press Process-For C5 Size Self-Supported I&E Fuel Elements", C. A. Burgess and G. M. Schweikhardt, July 1963.
5. HW-65759, "Proposed Solid State Diffusion Bonding (SSDB) Process--Gas Pressure Bonding", E. A. Weakley, June 22, 1960.
6. HW-47029, "Process Specifications Fuel Element Manufacturing Processes", J. T. Stringer, November 15, 1962.
7. HW-37677, Rev.6, "Producer Site Specifications for Uranium Fuel Element Cores"
8. HW-75758, "Design Criteria for Pilot Scale Plating Equipment--Project CAF-979", T. W. Gore, December 10, 1962.
9. HW-76858, "Interim Report on HDS Process Variables", C. A. Strand, May 20, 1963.

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10. HW-69886, Rev. 2, "Provisional Process Specifications for the Attachment of Projection Rails by Ultrasonic Spot Welding", J. T. Stringer, December 3, 1962.
11. Aluminum Component and Uranium Core Drawings:
H-3-17962, Rev. 1	Can Component CDB2N
H-3-17364, Rev. 3	Cap Component CDB2N
H-3-17363, Rev. 4	Core Component CDB2N
H-3-18206	AlSi Wafer CDB2N
12. HW-74625, "UT-4 - An Automatic Ultrasonic Tester for Closures of Hanford I&E fuels", D. O. Hunter, M. F. Zeutschel, May 1963.

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APPENDIX "A"

NICKEL PLATE QUALITY TESTING

Failure to pass the following tests shall be cause for more intensive evaluation and segregation of the affected cores.

1. Visual Inspection:

Each core shall be inspected as prescribed in Section 6 of this specification.

2. Adhesion Testing:

On one out of every 20 cores plated, remove a strip of nickel plate approximately 1/8 inch wide and at least one-half the length of the core with a sharp cutting tool. Examine the uranium-nickel junction at 5X magnification, or greater, for evidence of nickel-uranium separation.

3. Thickness Testing:

The nickel thickness is nondestructively tested on one core out of each 25 plated (the core used for adhesion testing may be used). The tester is a Dermitron, nondestructive, eddy current thickness tester. At least six readings are to be taken on the surface area of the core, excluding the last 1-1/2 inch on each end. These thickness readings shall not exceed the range of 0.0005 to 0.0011 inches for 25 minute plating time.

At least three readings are taken on the last 1-1/2 inches of each end. The thickness readings shall not exceed the

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range of 0.0009 to 0.0020 inches for a 25 minute plating time.

4. Discontinuity Testing:

Place one out of every 25 cores plated in an air atmosphere muffle furnace at 590 to 610 C (1090 to 1130 F) for 25 minutes. (The cores used in Adhesion and Thickness testing may be used.) Remove and allow to cool in ambient air. The core shall then be free of nickel plate discontinuities (as evidenced by oxide blisters) except at rack contact points, cracks in the uranium or where there is mechanical damage. Oxide blisters at the rack contact points shall not exceed 1/16 inch diameter.

5. Plate Ductility:

Once per day a nickel plate sample of at least 2 sq. in. and approximately 0.001 inch thick shall be prepared by plating on a surface to which the nickel adheres poorly (oxidized uranium or aluminum). The sample shall be bent through 180° and sharply creased. As a result, there should be no evidence of nickel cracking. Send a sample, approximately one square inch, to the lab for complete spectrographic analysis. Date and file the remaining sample along with the Hull cell plate (Ref: Appendix B #6).

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APPENDIX "B"

PROCESS CONTROL

SAMPLING SCHEDULE (For Laboratory Analysis)

<u>Solution</u>	<u>Process Step</u>	<u>Sample Frequency</u>	<u>Analysis Required*</u>
NaOH	Section 6 of this Spec. under Operating Technique. #1	None - make up fresh each Monday. Check Sp.Gr. with hydrometer daily - 1.10-1.13 - cold	
HNO ₃ (hot)	#3	Normal**	HNO ₃ U
Anodic Etch	#5	Normal** Check daily for gelatinous material on the bottom. Record results.	H ₃ PO ₄ HCl
HNO ₃ (warm)	#8	Normal**	HNO ₃ U
Plating Bath	#10	Every two days or every 50-60 cores, whichever is the most frequent. <u>Record time sampled.</u>	Ni ⁺⁺ pH Cl ⁻ NO ₃ -(ppm)
Nickel Plate		Same as for plating bath***	Spectrographic
Demineralized Water		Check last rinse before plating and final hot rinse at least once/4 hours with portable instrument.	

* All analytical results exclusive of uranium, BO₃⁼, NO₃⁻, and spectrographic should be available within four hours after the sample is submitted. All chemical compositions should be reported in Molarity unless otherwise specified.

** At startup and after processing 25 - 30 cores, record time sampled.

*** The observed boron content in the Ni plate is generally 10 ppm; 100 ppm maximum.

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1. Plating Bath pH

Check at least once per eight hours with the lab bench instrument, once on startup and once seven to eight hours later.

Adjust pH by:

If pH high, reduce by addition of HCl-H₂SO₄ mixture having the same SO₄⁼/Cl⁼ ratio as the plating bath (SO₄⁼/Cl⁼ = 5). This solution is a mixture of two parts by volume of conc. (39%) HCl plus seven parts by volume of conc. (98%) H₂SO₄. Record results and adjustments. If Cl⁼ or SO₄⁼ is high in the bath, add a single acid to maintain these ions within specifications.

If pH low, increase by addition of NiCO₃.

2. Plating Bath Clarity

Check at least once daily at startup by examining 500-1500 ml. sample against a strong light. Record results (i.e., presence of particulate matter, size, character, possible sources).

3. Anodic Etch

Examine one out of every 25 cores plated at a magnification of 20 to 40X for uniformity of etch.

4. Racks

Examine racks daily prior to use. Trim off loose plastic. Repair and replace contact points, plastic as needed.

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5. Sampling Results

Check with analytical lab daily and record results, keeping data current insofar as possible. All chemical compositions (exclusive of spectrographic) should be reported within four hours after the sample is submitted to the lab.

6. Hull Cell Test

Run a Hull cell plate once/shift at 5 amp., 10 minutes. Crease the plate 180° at approximately 1 inch from the high current density (HCD) end and at the HCD end. Examine at 20 to 40X. Note pits, roughness, discoloration, poor adhesion, cracks, and brittleness. Record results.

7. Demineralized Water (last rinse before plating and final rinse after plating)

Check with the ohm-meter at beginning and near end of shift and oftener if necessary. Maintain at > 500,000 ohm-cm.

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FIGURE 1 - URANIUM CORE - H-3-173 63,
REV. 4

FIGURE 2 - ALUMINUM CAN - H-3-17962,
REV. 1

FIGURE 3 - ALUMINUM CAP - H-3-17364,
REV. 2

NOTES:

1. Finish: Outside wall and internal wall surface scratches shall not exceed .005" in depth & surfaces shall be free of stains, galled and checked areas.
2. Flat surfaces -- machine finish ¹²⁵✓ max.
3. The 1.432" dia. & .437" dia. concentric to .006".
4. Aluminum alloy 8001-F.
5. Surface roughness symbols per A.S.A. Std. B46.1-1955.

FIGURE 4 - CLEANING OF ALUMINUM
COMPONENTS FOR HOT
DIE SIZING

Inspected Aluminum Components

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NOTES:

1. I.D. to be concentric with O.D. within 0.003".
2. Material as specified on order.

FIGURE 5 - ALSI WAFER

FIGURE 6 - ALSI WAFER PREPARATION

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FIGURE 7 - NICKEL PLATING
PROCESS FOR HDS
URANIUM CORES

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FIGURE 8

Nickel Plating Rack

FIGURE 9 - FLOW SHEET FOR
HOT DIE SIZE
FUEL ELEMENTS

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FIGURE 9 (Cont'd)

FIGURE 10

Dry Film Lubricant

FIGURE 11

Vacuum Dryer

FIGURE 12

Pre-Heat Carrier

FIGURE 13

Pre-Heat Furnace

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FIGURE 14

Sizing Press Schematic

FIGURE 15 - EXTERNAL AND INTERNAL
SIZING DIES

FIGURE 16 - END BONDING DIES

FIGURE 17

End Bonding Press

FIGURE 18 - HDS FUEL ELEMENT END CONTOURS

END

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