OVERVIEW OF THE FUEL FABRICATION CAPABILITY AND U-MO FABRICATION PROCESS

NAS MEETING #4

FEBRUARY 2015

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FUEL FABRICATION CAPABILITY TECHNICAL PILLAR LEAD

PNNL-SA-108171
FFC Mission

Develop the commercial-scale fabrication process for manufacturing the LEU fuel under development, including:

• Process development that does not adversely affect fuel performance or qualification; and

• Process optimization to reduce the eventual fuel manufacturing costs.

Specific FFC Goals

• Transfer fabrication knowledge and processes to the Y-12 National Security Complex and Babcock & Wilcox Nuclear Operations Group - Lynchburg; and

• Fabricate demonstration and experiment fuel products as requested by the program.
FFC STRUCTURE

NA-23
GTRI PM

Fuel Development
Pillar Lead

NF
B&W Contracts
FD Tech Transfer

ORNL
Tech-specific support

Y-12
Coupon Development and Fabrication
Scrap Recovery Operations

Fuel Fabrication Capability Pillar Lead

LANL
Tech-specific support

PNNL
B&W Contracts
Tech-specific support

B&W NOG
Foil and Plate Development and Fabrication
Scrap Recovery Operations

Reactor Conversion Pillar Lead

Cross Cutting Pillar Lead

OTHER
Aerojet, MSC, Universities
Tech-specific support
HISTORY OF THE FFC

• **2007:** FFC created to identify appropriate commercial entities for manufacturing of U-10Mo monolithic fuel with prototypic dimensions and throughput
  - Assumed conversion of all six USHPRRs with the same fuel form

• **2009:** NNSA industry assessment
  - No single manufacturing entity possessed the necessary equipment and know-how to fabricate U-10Mo monolithic fuel, either in the US or abroad

• **2009-2011:** FFC worked towards transferring the fuel fabrication technology developed by the fuel development (FD) team at the laboratory scale to a commercial manufacturer
  - Limited scoping studies were conducted to determine the feasibility of scaling the fabrication concept to appropriate size and throughput

• **2011-2012,** subsequent work focused on establishing a limited production facility to demonstrate prototypic-scale manufacturing of the fuel
  - Initially Y-12 coupons & foils; LANL plates; B&W NOG elements
  - Later Y-12 coupons & foils; B&W NOG plates & elements
  - Finally Y-12 coupons; B&W NOG foils, plates & elements

• **2012-present:** Realized need for optimization of the baseline concepts and consideration of alternative concepts where they offer potentially significant product quality, cost, or throughput advantages
  - FFC has embarked on an applied R&D program to evaluate fabrication parameters and their effect on manufacturing efficiency and product quality
  - Additional consideration for the work that will be necessary to fully define acceptable manufacturing processes for “complex” fuel to include HPRR-specific features such as fins, contoured fuel meat, and integral burnable absorbers
USHPRR Existing Referenced Fuel Fabrication Process Flow

**Downblend and Alloying**
- HEU Feed
- Low-Enrichment Diluent
- Alloy Material
  - Metal Blending
  - Intermediate Product
  - Scrap Recovery

**Casting and Coupon Preparation**
- Final Casting
- LEU-Mo Ingot
- Machine into Coupons in Preparation for Rolling
  - Scrap Recovery

**Foil Rolling**
- Can Zr & Coupon using Arc or E-Beam Welder
- Heat Coupons
- Co-Hot Roll Coupons
  - Cold Roll to Final Thickness
  - Shear to Foil Dimensions
  - Various Foil Sizes Produced from a Standard Coupon
  - Scrap Recovery

**Forming and Assembly**
- Series of Curved Plates Form Complete Elements
  - Flat Plates Bent Over Form to Curve
  - Scrap Recovery

**Hot Isostatic Pressing**
- Fuel Plates
- Hot Isostatic Pressing
  - Foils & Al/Steel
  - Scrap Recovery
PILOT FOIL FABRICATION LINE

• Pilot Foil Fabrication Line installation completed at B&W Nuclear Operations Group- Lynchburg, VA
  • Facility modifications (floor plan, electrical, HVAC, flooring, ceiling, lighting, etc.)
  • New equipment
  • Some existing equipment will be leveraged
• Equipment procured based on fuel specification requirements available at the time
• Current focus at B&W is process and procedure development (through April 2015)
Simplified HIP Can Ass’y Flowsheet

- Al Cladding Stock
  - Machine Al Pocket Plates
  - Clean Covers and Pocket Plates
  - Etch Covers and Pocket Plates
- HIP Can Tubing Stock
  - Cut HIP Can Tubing to Length
  - Weld HIP Can Frame, Cover, and Tubing
- HIP Can Frame and Cover Stock
  - Machine Window in HIP can Frames
  - Machine Edges in HIP Can Frames
  - Degrease HIP Can Frames and Covers
- Load Plate Strip
  - Machine Load Plates
  - Degrease Load Plates
  - Coat Load Plates with Neolube
- Foils
  - Clean Foils
  - ID HIP Pack
  - Assemble HIP Can Parts
  - HIP Can
Simplified Plate Mfg Flowsheet

1. HIP Can
2. Weld HIP Can Cover
3. HIP Can He Leak Check
4. HIP Can Bakeout
5. HIP Can Tubing Sealed
6. Load HIP Can into Fixture
7. Load Fixture into Furnace
8. Load Assembly into HIP
9. Process HIP
10. Cool and Unload HIP Assembly
11. Disassemble HIP Can
12. Rough Shear Plates
13. X-Ray Punch Plate for Location
14. Machine Plate to Final Width
15. Machine Plate to Final Thickness
16. Deburr Edges of Plate
17. Insp?
   - Y: Fuel Plates
   - N: Scrap

Fuel Plates

Scrap
Baseline Process Optimization

- Clad-to-Foil Thickness Ratio Effect on HIP (1.2.1.5)
- Clad-to-Foil Thickness Ratio and Bend Radius Effects on Forming (1.2.1.6)
- HIP Can Optimization (1.2.4.2)
- Plate Trimming by Laser (1.2.4.8)
- Inspection Methods to Improve Plate Machining Efficiency (1.2.4.10)
- Can-Less HIP (1.2.4.16)
- Machining with Time-Saver
- Manufacturing Plates with Fins

Alternative Process Demonstration

- Net-Shape HIP Bonding
- Hot Pressing
- Zr-Base Alloy Cladding
Element Manufacturing

Baseline Process Optimization
  - Swaging Borated Side Plates
  - Welding Borated Side Plates

Alternative Process Demonstration
  - Fuel Element Ass’y with Zr-Base Alloy Cladding

Cross-Cutting R&D
  - Source Material Availability (1.2.4.3)
  - Overall Process Modeling (1.2.4.19)