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EBR-II SPENT FUEL TREATMENT DEMONSTRATION PROJECT

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DISCLAIMER

Introduction

For approximately 10 years, Argonne National Laboratory was developing a fast reactor fuel cycle based on dry processing.[1] When the U.S. fast reactor program was canceled in 1994, the fuel processing technology, called the electrometallurgical technique, was adapted for treating unstable spent nuclear fuel for disposal. While this technique, which involves electrorefining fuel in a molten salt bath, is being developed for several different fuel categories, its initial application is for sodium-bonded metallic spent fuel. In June 1996, the Department of Energy (DOE) approved a radiation demonstration program in which 100 spent driver assemblies and 25 spent blanket assemblies from the Experimental Breeder Reactor-II (EBR-II) will be treated over a three-year period. This demonstration will provide data that address issues in the National Research Council's evaluation[2] of the technology. The planned operations will neutralize the reactive component (elemental sodium) in the fuel and produce a low enriched uranium product, a ceramic waste and a metal waste. The fission products and transuranium elements, which accumulate in the electrorefining salt, will be stabilized in the glass-bonded ceramic waste form. The stainless steel cladding hulls, noble metal fission products, and insoluble residues from the process will be stabilized in a stainless steel/zirconium alloy. Upon completion of a successful demonstration and additional environmental evaluation, the current plans are to process the remainder of the DOE sodium bonded fuel.

Planned Operations

The fuel treatment demonstration will utilize the Fuel Conditioning Facility (FCF). The process steps are shown in Figure 1 and include fuel assembly dismantling, element chopping, electrorefining, cathode processing, casting and waste processes. Fuel assembly dismantling removes the individual stainless steel clad elements from the assembly hardware. These elements are sheared at the element chopper into fuel segments, which contain the metal fuel. The driver elements (~4.1 kg uranium per assembly) are sheared with a small existing chopper while a larger capacity blanket element chopper will be installed for the larger diameter blanket elements (~47 kg uranium per assembly).

Chopped driver fuel segments will be placed in anode baskets that are placed in the MK-IV Electrorefiner. This electrorefiner[3,4,5] has a 1 m diameter vessel with a 10 cm layer of molten cadmium and a 30 cm layer of molten salt held at 450-500°C. The electrorefiner has four ports for two anodes and two cathodes that can process two 10 kg loads of uranium, simultaneously. For blanket fuel treatment, which will demonstrate higher specific throughput, a second (Mk-V) electrorefiner will be installed in FCF in late 1997. It has an identical vessel with four ports; however, each port has a concentric anode cathode module that holds 37 kg loads of uranium. The four anode-cathode modules (total of 150 kg uranium) can be processed simultaneously.

After electrorefining, the cathode products are transferred to the cathode processor, an induction-heated vacuum distillation furnace. The residual salt and cadmium are removed from the uranium and recycled to the electrorefiner. The consolidated uranium product is transferred to the casting furnace, which is also an induction-heated device. The uranium product is mixed with depleted uranium to produce a homogeneous low enriched uranium product (< 20% ^{235}U). A metal waste form[6,7] is produced by mixing 15% zirconium with the stainless steel cladding hulls that are removed from the electrorefiner. The process steps are very similar to the uranium cathode process steps.

The majority of the fission products and transuranium elements accumulate in the electrorefiner salt. A major demonstration objective is to show that these fission products can be incorporated into a stable ceramic waste form[8] that is suitable for a geologic waste repository. In the demonstration, a portion of the electrorefiner salt will be mixed with zeolite powder in a V-blender that can operate

up to 600°C. After the salt is absorbed into the zeolite, glass materials will be mixed with the zeolite. This powder mixture will be loaded into waste cans that are evacuated and seal welded. The cans are transferred to a hot isostatic press that converts the material to a ceramic monolith.

The 100 driver assemblies will be processed in the Mk-IV electrorefiner producing a fission product concentration in the salt reaching approximately 3 weight percent. The Mk-V electrorefiner will treat the blanket assemblies and demonstrate higher processing rates. Irradiated cladding hulls from the driver fuel will be used for the metal waste samples and a portion of the Mk-IV electrorefiner salt will be converted to ceramic waste samples.

Process Results

The main process steps have been operating in FCF since June 1995. Initially, depleted uranium and a depleted uranium-zirconium alloy were used to test the process equipment. Since June 1996, twenty-four irradiated fuel assemblies have been electrorefined and seventy-one kilograms of highly enriched uranium have been converted to low enriched uranium product. One non-radioactive and one irradiated cladding hull ingot have been cast. The ceramic waste process equipment is being tested with non-radioactive simulated waste before installation in the hot cells.

Driver processing rates are scheduled to double in August 1997. Blanket treatment operations with the new Mk-V electrorefiner and blanket element chopper will start in March 1998. Ceramic waste operations with salt from the Mk-IV electrorefiner should start in February 1999 and the demonstration should be completed in June 1999.

Acknowledgments

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References

1. W. H. HANNUM, editor, "The Technology of the Integral Fast Reactor and its Associated Fuel Cycle," special issue, *Progress in Nuclear Energy, Vol.31* (1997).

2. NATIONAL RESEARCH COUNCIL, "An Assessment of Continued R&D into an Electrometallurgical Approach for Tracking DOE Spent Nuclear Fuel," Committee on Electrometallurgical Techniques for DOE Spent Fuel Treatment, Washington, D.C. (1995).

3. R. D. MARIANI and D. VADEN, "Initial Electrorefining Operations with Spent Fuel from EBR-II at ANL-West," *Transactions of the American Nuclear Society, Vol. 76*, 70 (1997).

4. K. M. GOFF, R. D. MARIANI, D. VADEN, N. L. BONOMO, and S. S. CUNNINGHAM, "Fuel Conditioning Facility Electrorefiner Start-Up Results," *DOE Spent Nuclear Fuel and Fissile Material Management, American Nuclear Society*, 137 (1996).

5. J. P. ACKERMAN, "Chemical Basis of Pyrochemical Reprocessing of Nuclear Fuel," *I and E.C. Research 30(1)*, 141 (1991).

6. D. P. ABRAHAM, S. M. MCDEAVITT, and J. PARK, "Metal Waste Forms From the Electrometallurgical Treatment of Spent Nuclear Fuel," *DOE Spent Nuclear Fuel and Fissile Material Management, American Nuclear Society*, 123 (1996).

7. B. R. WESTPHAL, D. D. KEISER, R. H. RIGG, and D. V. LAUG, "Production of Metal Waste Forms From Spent Fuel Treatment," *DOE Spent Nuclear Fuel Challenges & Initiatives, American Nuclear Society*, 288 (1994).

8. C. PEREIRA, M. A. LEWIS, and J. P. ACKERMAN, "Overview of Mineral Waste Form Development for the Electrometallurgical Treatment of Spent Nuclear Fuel," *DOE Spent Nuclear Fuel and Fissile Material Management, American Nuclear Society*, 129 (1996).

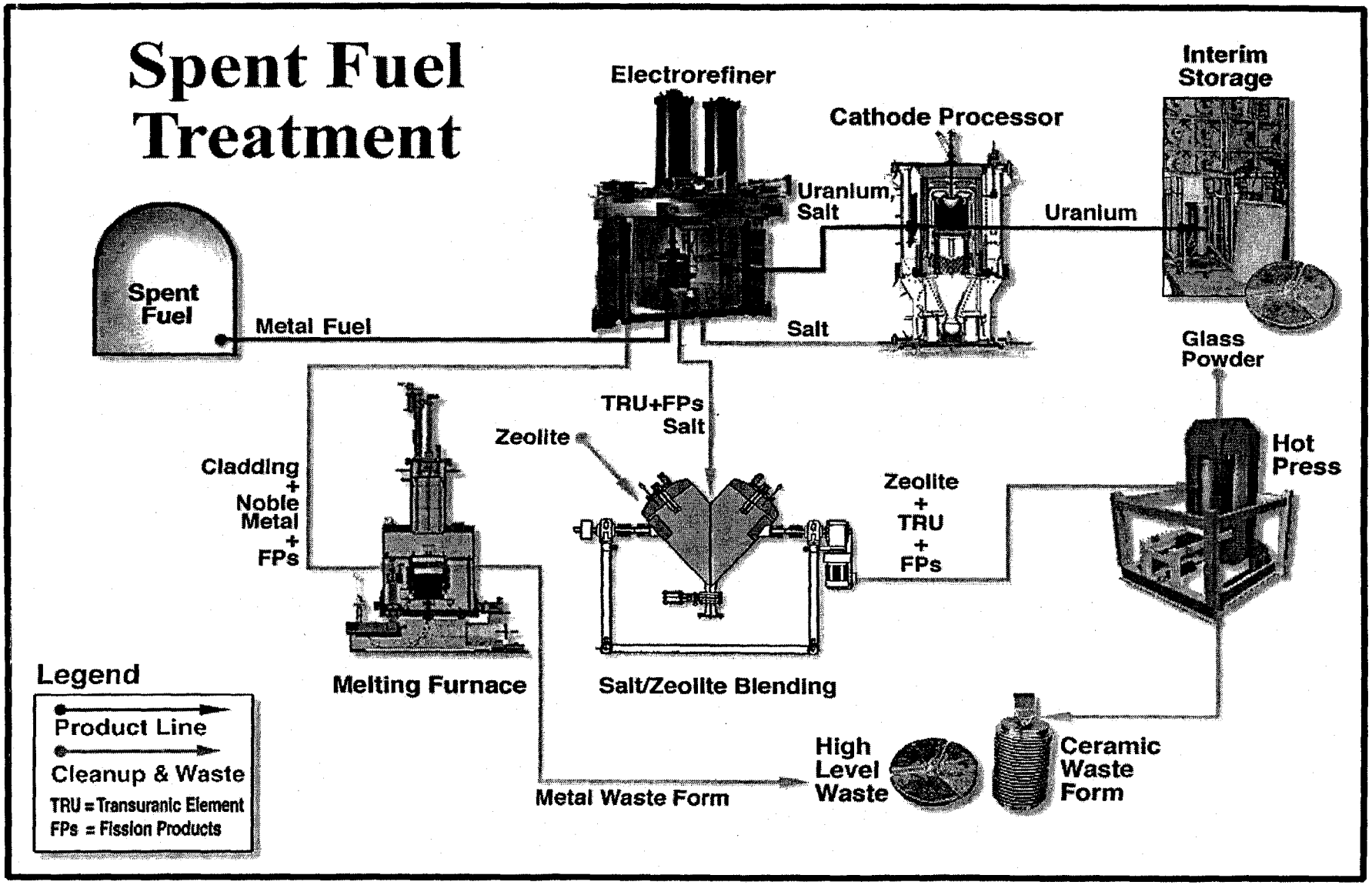

Figure 1. EBR-II Spent Fuel Treatment Process Steps