Task 1

Design and Analysis of a Process for Melt Casting Metallic Fuel Pins Incorporating Volatile Actinides

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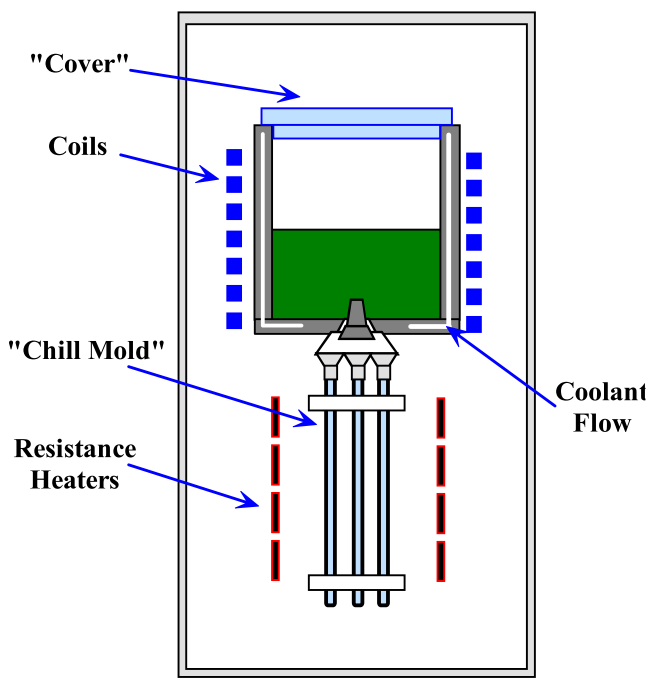
BACKGROUND

The Transmutation Research Program requires the incorporation of non-fertile actinides into the fuel matrix for the transmuter blanket. One of three currently proposed candidate matrices for the transmuter is a metallic alloy fuel matrix. Metallic fuels are an outstanding candidate for a transmutation fuel due to excellent irradiation performance and ease of fabrication. However, incorporating a volatile constituent during fabrication of these fuel pins presents a challenge.

Volatile actinides, particularly americium, are susceptible to rapid vaporization during the traditional metal fuel casting processes. The actinide vapors boil off, and flow out of the system into the off-gas recovery system, resulting in only a fraction of the volatile actinide charge being incorporated into the fuel pins. The loss of these actinides from the fuel greatly complicates the task of preparing them for transmutation, requiring additional recovery and fuel fabrication steps to try to incorporate the volatile actinides into the transmuter fuel.

The goal of this project is to investigate the casting processes for metallic fuels to help design a process that minimizes the loss of the volatile actinide elements from the fuel.



Schematic of proposed induction skull melting furnace for the casting of high americium content fuels.

The research effort centers on the development of advanced numerical models to assess conditions that significantly impact the transport of volatile actinides during the melt casting process and represents a joint effort between researchers at the University of Nevada, Las Vegas (UNLV) and Argonne National Laboratory (ANL).

RESEARCH OBJECTIVES AND METHODS

The objective of this research is to assist in implementing technology that will eventually be applicable to transmutation fuel fabrication on a production scale. Assessing critical equipment and process variables required to build a successful system will do this. Additionally, a cooperative effort between UNLV and ANL establishes a working relationship that assists with developing an approach to generate the next casting furnace for the Advanced Fuel Cycle Initiative (AFCI) program.

RESEARCH ACCOMPLISHMENTS

<u>Development of the induction-heating model</u>: Modeling efforts centered on the development of the governing equations, incorporating these equations into computer codes, setting up a test problem, and making preliminary calculations for the geometry of interest.

<u>Modeling of casting process:</u> Efforts continued to improve a model for the casting of fuel pins. Work considered the flow of the melt into the mold and heat transfer into the mold during solidification (after flow has stopped). Results from an energy balance model indicate that the thermal mass would typically be greater than needed to solidify the melt within the mold. The results of this simple model have aided in designing a mold to hold and solidify the fuel pins.

<u>Parametric Analysis of Casting Process:</u> In order to test the impact of process parameters (temperature, pressure, alloying elements, etc.) on the casting process, a parametric study of the casting model was performed on different processing parameters. These studies centered around model development and analysis of the impact of mold preheating on heat transfer into the model. Results will assist with determining which process parameters are critical in manufacturing a suitable metallic fuel pin.

<u>Americium Transport Models:</u> A model that analyzes the transport of americium from the melt to the vapor phases above the crucible has also been developed. The model considers mass transport in the melt, vaporization at the surface, and transport through the vapor phase. Parametric studies are underway to evaluate the impact of different properties or situations on the transport of americium from the melt.

<u>Casting Furnace Performance Model:</u> Researchers in the group developed more detailed heat and mass transfer models that could be used successfully in the analysis of an advanced casting furnace design.

<u>Develop Prototype Furnace Design:</u> A preliminary furnace design that can be built and tested with surrogate materials is critical in order to assess the viability of metal fuels. A preliminary analysis of potential surrogate materials has been completed. Manganese appears to be an acceptable surrogate material. Discussions will be held with Argonne National Laboratory staff members to insure that no health and safety issues prevent manganese from being used in future tests.

FUTURE WORK

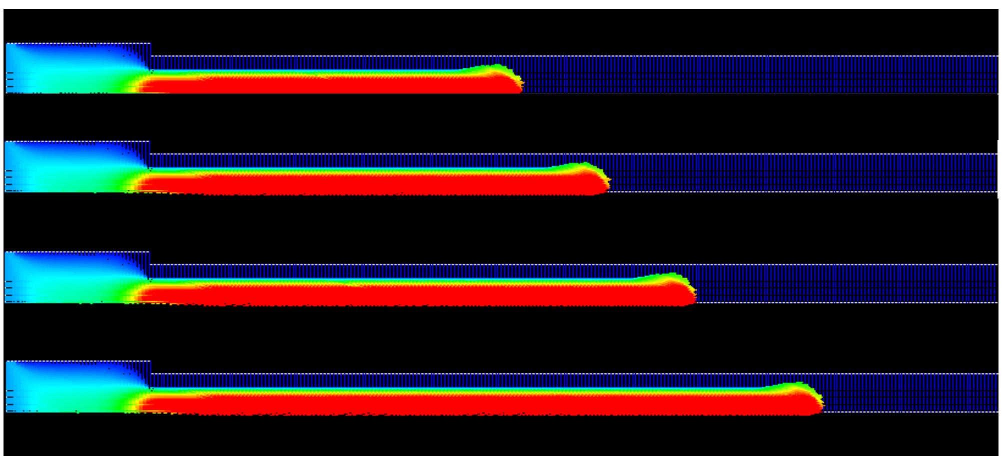
The following are the research objectives for the next year of this project:

- Continue analysis of americium transport and loss from the melt process using the combined heat and mass transfer models developed at UNLV.
- Continue to revise and refine the combined heat and mass transfer model of representative furnace geometry.
- Benchmark and validate the model through comparisons to experimental tests.
- Perform a series of engineering analyses with the models to aid in the design of the next generation casting furnace.

HIGHLIGHTS

- "An Analysis of the Melt Casting of Metallic Fuel Pins" presented at the ASME International Mechanical Engineering Congress, New Orleans, LA, November 17-22, 2002.
- "An Analysis of the Melt Casting of Metallic Fuel Pins" presented at the AFCI Semi-Annual Review Meeting, Albuquerque, NM, January 22-24, 2003.
- "Numerically Simulating the Solidification Process of a Melt Casing Metallic Fuel Pin Mold Using FIDAP" presented at the ANS Student Conference, Berkeley, CA, April 2-6, 2003.
- Abstract "Simulation and Analysis for Melt Casting a Metallic Fuel Pin Incorporating Volatile Actinides" submitted to the ASME International Mechanical Engineering Congress and R&D Expo, Washington, DC, November 16-21, 2003.

Engineering Analyses for the preliminary design of the furnace will be carried out in conjunction with ANL-West staff. System throughput, processing rates, material handling, and other pertinent issues will be taken into consideration as the next generation casting furnace is developed. A detailed model will be used for the preliminary design of an inductively heated skull-crucible casting furnace, designed to be remotely operated in a hot cell environment, which is one of the primary concerns of the AFCI program.



Velocity vectors of melt flowing into chill mold (transient conditions). Red represents high velocities; blue represents lower velocities.

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