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

Yitung Chen

*University of Nevada, Las Vegas, yitung.chen@unlv.edu*

Darrell Pepper

*University of Nevada, Las Vegas, darrell.pepper@unlv.edu*

Randy Clarksean

*University of Nevada, Las Vegas*

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## Task 1

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

Y. Chen, D.W. Pepper, and R. Clarksean

## 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 blanket 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, including a volatile constituent during fabrication of these fuel pins presents a challenge.

High vapor pressure actinides, particularly americium, are susceptible to rapid vaporization and transport using traditional metal fuel casting processes. As a result, only a fraction of the desired charge is incorporated into the fuel pins. This proves unacceptable from a materials accountability standpoint and fails to meet the objective of including these actinides in the fuel for transmutation.

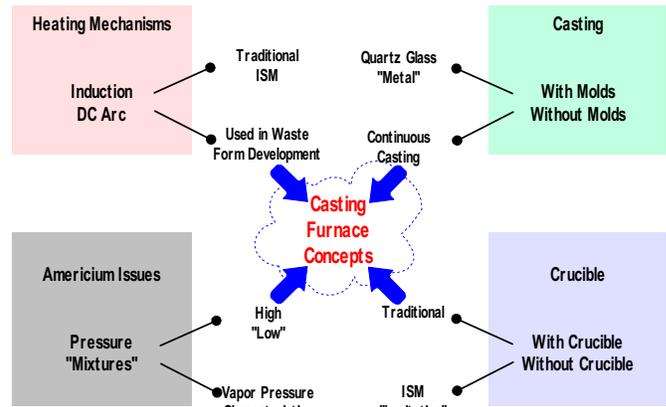
The goal of this project is to model and investigate the casting processes for metallic fuels to help design a process that minimizes the loss of the volatile actinide elements, such as americium, from the fuel.

## OBJECTIVES

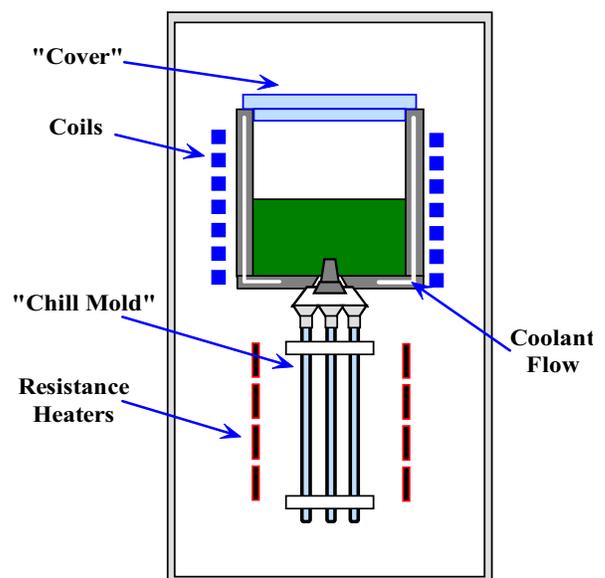
Three research objectives were defined for year one. The first objective was to document volatile actinide transport properties and issues. Using this information, the project was to then develop a parametric model for volatile actinide transport during casting, and then use that model to evaluate the various melt casting technologies. Based on the results of this work, the research group, along with their collaborators from ANL-West, were to select the melt-casting process(es) most suitable for the casting of metallic fuel pins containing volatile actinide elements.

## ACCOMPLISHMENTS

The following illustration outlines the mechanisms and furnace options evaluated in the design process:



As a result of considering these variables, the conceptual design of the next generation metallic casting furnace has been proposed. The furnace concept uses an induction skull melter (ISM), covered crucible region, chill molds, and resistance heaters to control the preheating of the molds. The induction skull melting technique, shown below, allows for the control of americium transport as well as the length of the fuel pins that can be cast.



The proposed process theoretically achieves great melting efficiencies and minimizes potential contamination during the melting processes. The crucible cover selected controls the transport of americium from the melt. Resistance heaters control preheating of the molds and insure that the melt will flow into the molds. Chill molds permit proper geometric control. The melt will then flow into the molds either by gravity or through pressurization.

Additionally, the models needed to analyze the performance of the ISM and other furnace designs are being developed. Currently, the model of the furnace system consists of the following components: the casting rod model, the induction heating model, and the mass transfer model. The casting rod heat transfer model considers the flow of the melt into a chill mold. The induction heating model assists in determining the amount of heating produced by the system. Finally, the mass transfer model considers transport within the melt, vaporization at the interface, and transport in the gas phase. The modeling work in the first year focused on the development of these models and examined the possibility of modeling the thermal field within the furnace using a heat transfer code. The development of these models has been completed.

### CONTINUED PROGRESS AND FUTURE GOALS

The successful incorporation of volatile actinides in metallic fuel pins requires further research and collaboration over the next two phases of this research. Continued model benchmarking and evaluation includes applying heat transfer and fluid mechanic effects. Activities of Am in molten U-Am and Pu-Am will be calculated and the controlling steps of the mass transfer process will also be studied. The final phase of this research involves a joint effort between UNLV and Argonne National Laboratory to demonstrate the acceptable use of the new furnace in a simulated remote environment. This includes the design and modification/fabrication of a small test furnace for remote operation.

### HIGHLIGHTS

- Travel to Argonne National Laboratory to discuss issues related to casting process selection as well as modeling and research efforts prior to submitting the final report.
- A stipend research assistantship for a M.S. graduate student in the Mechanical Engineering department. M.S. granted in May 2002.
- Two research papers were submitted to the International Mechanical Engineering Congress and Exposition and the International Congress on Advanced Nuclear Power Plants related to metallic fuel pins furnace design.
- Four presentations were given at the following workshops/conferences: American Nuclear Society Winter Conference (Reno 2001); ANL Transmuter Fuel Development Workshop (Idaho, November, 2001); International Youth Nuclear Congress 2002 (Korea); and a TRP seminar (October 2001).



*Xiaolong Wu received his M.S. in Mechanical Engineering May 2002.*

#### Research Staff

Yitung Chen, Principal Investigator, Assistant Director, UNLV Nevada Center for Advanced Computational Methods  
Darrell W. Pepper, Dean, UNLV College of Engineering  
Randy Clarksean, Adjunct Professor, Mechanical Engineering Department

#### Students

Xiaolong Wu, Graduate Student, Mechanical Engineering Department  
Paul Lawson, Undergraduate Student

#### Collaborators

Mitchell K. Meyer, Leader of Fabrication Development Group, Nuclear Technology Division, Argonne National Laboratory  
Steven L. Hayes, Manager of Fuels & Reactor Materials Section, Nuclear Technology Division, Argonne National Laboratory