NUCLEAR ENERGY RESEARCH INITIATIVE

Optimized, Competitive Supercritical-CO_2 Cycle GFR for GEN-IV Service

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Project Number: 05-044

Collaborators: None

Related Program: Gen IV

Project Description

This project will develop an integrated overall plant design for a gas-cooled fast reactor (GFR) based on the compact and highly efficient, direct supercritical carbon dioxide (CO_2) Brayton cycle. This plant will be capable of performing a full spectrum of desired GEN-IV objectives, including economical electric power generation, high uranium utilization, the ability to burn transuranics and/or minor actinides, and production of hydrogen through the high-temperature electrolysis of steam. There are tradeoffs associated with achieving attractive economics and assuring a high degree of safety for the final plant design. Researchers will use probabilistic techniques to optimize these tradeoffs and develop a design that is both economical and safe. In addition, researchers will use existing NRC deterministic prescriptions and proposed risk-informed licensing requirements to evaluate prospective plant designs.

Most worldwide research on this type of gas reactor is based on a helium cycle that operates at temperatures approaching 900 °C, which poses severe core and component material challenges. This S-CO_2 cycle can achieve high thermodynamic efficiency (approximately 44% to 51%) at modest temperatures of 550 to 650 °C. Therefore, creative synthesis of proven technology should suffice in many instances. The focal point of major tasks of this project will be designing the reactor core and the decay heat removal systems. Overall, this project will provide a sufficient basis for assessing this type of GFR among the candidate GEN IV designs being evaluated for final selection.

Work Scope

Task 1: Core design and performance assessment

- Optimize features of vented fuel concept using tube-in-duct assemblies
- Develop pin type core design as benchmark for comparisons and as a fallback option
- Confirm the burning capability of TRU and minor actinides

Task 2: PRA guided design of safety systems

- Develop decay heat removal design for accident, normal shutdown and refueling
- Develop improved emergency power systems, such as microturbines or fuel cells
- Develop both active and passive means of shutdown assurance to preclude ATWS

Task 3: Overall plant design and economic assessment

- Design power cycles for core exit temperatures ranging from 550 to 700 °C
- Demonstrate integration with high temperature electrolysis of steam for H_2 production
- Estimate busbar costs of electricity relative to other reactor options.