Statement of Problem

Nuclear energy is one of the most favorable and cheapest alternatives to fossil fuels, and it can be scaled up to meet global energy demands. The mass deployment of nuclear energy as a low-emissions source requires the reprocessing of used nuclear fuel to recover fissile materials and mitigate radioactive waste. A major concern with reprocessing used nuclear fuel is the release of gaseous radionuclides such as iodine, tritium and krypton that evolve into the reprocessing facility off-gas in parts per million concentrations. For the fuel reprocessing process to be feasible, effective radionuclides separation processes must be developed.

Technical Approach

Upon completion of this research program, Tetramer will have developed an effective separation process for Xe/Kr from nuclear fuel dissolver off-gas streams. The proposed approach will utilize selective sorbents based on metal organic framework and/or zeolites. To achieve project goals, sorbents will be screened and formulated into a structured form suitable for practical separation processes. After sorbents characterization, the separation process will be modelled to find the optimized conditions. Finally, the separation process will be demonstrated on lab scale.

At the end of this Phase I, Tetramer anticipates demonstrating a continuous, cost-effective adsorption process for Xe and Kr from nuclear fuel dissolver off-gas streams with new structured sorbent materials and modeling a multi-stage Xe/Kr separation process.

Phase I Work Plan

During Phase I, a separation process for the concentration of Xe and Kr from nuclear fuel dissolver off-gas streams will be developed through three objectives. In the first objective, a suitable material will be selected for utilization in Xe/Kr separation. After characterization, the selected adsorbent material will be formulated into a structured sorbent material for practical Xe/Kr separations. The second objective will focus on modelling of the separation process. The third objective will demonstrate the separation process on lab scale.

The performance and technoeconomic feasibility of the process will be evaluated based on the data collected from the combined Phase I Objectives. The development, optimization, and prototype demonstration of the structured sorbent materials and complete multi-stage process will be proposed for the Phase II program.

Commercial Applications and Benefits

Currently the United States does not reprocess spent nuclear fuel and utilizes a “once through” nuclear cycle approach. The potential to reprocess nuclear fuel would significantly reduce the waste generation from nuclear energy and could even allow for an additional nuclear fuel cycle to generate additional energy. One of the critical challenges that must be met to enable nuclear fuel reprocessing is the selective capture of Xe/Kr from off-gas during shearing and dissolving of spent fuel rods. The technology developed through this SBIR program will dramatically improve the economics of Xe/Kr separation and reduce the volume of radioactive Kr gas that must be stored, enhancing the feasibility of closed nuclear fuel cycles.

Key Words

Nuclear energy, fuel reprocessing, xenon, krypton, sorbent, multi-bed separation process, metal organic frameworks, zeolites

Summary for Members of Congress

Nuclear energy is one of the most favorable and cheapest alternatives to fossil fuels. Vast utilization of nuclear energy as a low-emissions source requires the reprocessing of used nuclear fuel to recover fissile materials. However, the reprocessing process is accompanied by emissions of harmful radioactive isotopes. Development of a separation process capturing these isotopes will greatly enhance the feasibility of closed nuclear fuel cycles, reducing the overall carbon footprint of the US economy.