Contract No:

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Disclaimer:

LDRD-2015-00005

LDRD External Report Summary

Alternate Tritium Production Methods Using a Liquid Lithium Target

For over 60 years, the Savannah River Site's primary mission has been the production of tritium. From the beginning, the Savannah River National Laboratory (SRNL) has provided the technical foundation to ensure the successful execution of this critical defense mission. SRNL has developed most of the processes used in the tritium mission and provides the research and development necessary to supply this critical component. This project was executed by first developing reactor models that could be used as a neutron source. In parallel to this development calculations were carried out testing the feasibility of accelerator technologies that could also be used for tritium production. Targets were designed with internal moderating material and optimized target was calculated to be capable of 3000 grams using a 1400 MWt sodium fast reactor, 850 grams using a 400 MWt sodium fast reactor, and 100 grams using a 62 MWt reactor, annually.

Awards and Recognition

PI received a Laboratory Director's Award for their participation in this project and other work during the fiscal year.

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publically published in its current form.

SRNL Legal Signature

Signature **Date**

LDRD-2015-00005

LDRD Report

Alternate Tritium Production Methods Using a Liquid Lithium Target

Project Team: J. Wilson, S. J. Branney, C. G. Verst, S. O. Sheetz, and C. M. Mussi

Subcontractor: None\

Thrust Area: ST3

Project Type: Standard

Project Start Date: October 1, 2014

Project End Date: September 30, 2015

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FY2015 Objectives

- Examine different methods that have been studied for the production of tritium to determine which are the most feasible.
- Using MCNP and ORIGEN, Develop initial models for scoping calculations to see if the chosen technologies will be able to meet tritium production needs.
- Develop and evaluate different liquid lithium targets to optimize production of tritium.
- Incorporate the different targets into the models to find the optimal combination for production and impact on unobligated US origin Uranium.

Introduction

For over 60 years, the Savannah River Site's primary mission has been the production of tritium. From the beginning, the Savannah River National Laboratory (SRNL) has provided the technical foundation to ensure the successful execution of this critical defense mission. SRNL has developed most of the processes used in the tritium mission and provides the research and development necessary to supply this critical component. Utilizing the results of Texas A&M University (TAMU) senior design projects on tritium production in four different small modular reactors (SMR), SRNL developed a model evaluating tritium production versus uranium utilization [1]. The SRNL Technical Advisory Committee (TAC) ran a Monte Carlo N-Particle (MCNP) model of a basic Sodium Fast Reactor for Comparison [2]. As a result, it was concluded to leverage an approved LDRD program at SRNL for extraction of tritium from liquid lithium. This analysis examined alternative methods of producing tritium using a liquid lithium target or blanket, instead of using solid targets, which will allow for continuous production and extraction of tritium from the blanket and build upon the current LDRD investigating separation of lithium-tritide within liquid lithium. This analysis investigated different modes of producing neutrons and tritium, fast reactors, heavy water reactors, and other technologies. This analysis also branched out and looked at the potential of using solid lithium targets for the production of tritium.

Approach

The approach taken for this project was to examine various neutron source technologies that could be used for the production of tritium utilizing a liquid lithium target or blanket. Starting point for liquid target design was to examine fusion breeding blankets and try to utilize the work that has been done on tritium production for fusion power systems. Using the knowledge that has been gained from the research that has been completed on these systems, the initial design took a very large blanket around a sodium fast reactor made of natural lithium.

This project was executed by first developing reactor models that could be used as a neutron source. In parallel to this development calculations were carried out testing the feasibility of accelerator technologies that could also be used for tritium production.

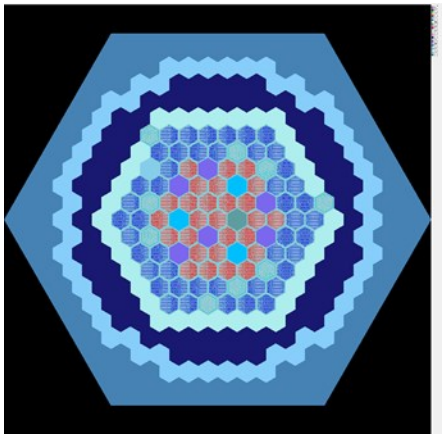

Figure 1. 400 MWt Sodium Fast Reactor Used for Initial Target Development.

Results/Discussion

Three reactors were modeled to use as a neutron source for this project. The first was a 62 MWt sodium cooled fast reactor using a metal U-Zr fuel. The next reactor modeled was a 400 MWt sodium cooled fast reactor fueled with UO_2 ceramic fuel. The final reactor that was modeled for this project was 1400 MWt sodium cooled fast reactor that was fueled with U-Pu-Zr, U-Zr, Pu-Zr and MOX fuel. The reason sodium fast reactors were used for this effort was the operating experience of the sodium fast reactors and the available literature on the different reactors. Choosing to examine a fast reactor was to try and take advantage of the higher energy neutron spectrum. The higher leakage of neutrons from the core of a fast reactor was another reason they were utilized in this project. By utilizing the leakage neutrons, for an external target, it would be possible to design a core that would be able to be utilized for a longer cycle with lower fissile content than one with internal targets.

These three reactors were modeled with simple targets which were just a cylindrical shell on the outside of the reactor. These targets were modeled with varying rations of Li-6 enrichment, from natural lithium to a fully enriched Li-6 target. From these initial models it was obvious that the external target would need to have some type of moderating material designed into the target to increase tritium production. From these models it was obvious that the 62 MWt reactor did not produce enough leakage neutrons to be a viable production source. Target optimization was carried out on the 400 MWt reactor. The targets were designed with internal moderating material, polyethylene clad in stainless steel was used, and without a variation in size from the initial models. This was done so that the effects of the various amount of moderation and lithium enrichment values could be varied with direct comparison the initial models. The maximum production in this target design with the 400 MWt reactor was calculated to be 800 grams of tritium annually with pure Li-6 target and 700 grams annually with a natural lithium target. These targets were massive and were not a feasible design to be considered for actual production. The next step was to utilize the 1400 MWt reactor model to develop a more reasonably sized target.

The optimization of the target was done by selecting multiple moderator geometries and size of the vessel that contained the lithium and moderator. The result of this optimization was a target that would run on the leakage neutrons from the 1400 MWt reactor and was calculated of being capable of producing 3200 grams of tritium annually, using natural lithium and 4500 grams with pure Li-6. The next step that was taken was to examine the same type of target with solid lithium in various forms, Li-Al alloy, LiAl2O, and LiO2. Though these solid targets performed slightly worse than the liquid target, they were calculated to still be capable of producing up to 3000 grams of tritium annually with natural lithium.

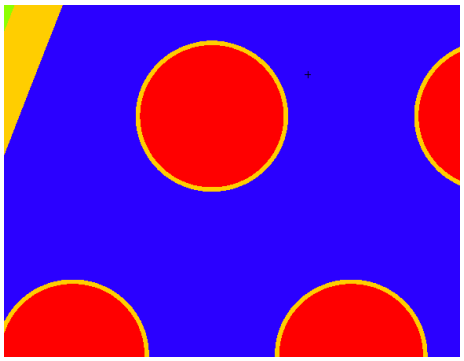

Figure 2. Section of the liquid lithium target after optimization (blue-lithium, red-moderator, yellow-steel)

FY2015 Accomplishments

- Developed a potential replacement target design to the current tritium production method that can be adapted to any reactor design.
- Evaluated current fusion system tritium breeding concepts and possible incorporation into other tritium production technologies.

Future Directions

This project will feed into the discussions on the next generation of tritium production and can be leveraged into tritium breeding work for fusion power systems.

FY 2015 Publications/Presentations

None

References

1. S. Sheetz, M. Jones, and J. Wilson, “PDRD (SR13046) Tritium Production Final Report,” SRNL-STI-2013-00547, Revision 0, September 2013.
2. Milton E. Vernon, Steven A. Wright, and Paul S. Pickard, “TAC Report: Evaluation of Tritium Production with Small Modular Reactors,” SRNL Technical Advisory Committee, August 2013.

Acronyms

Li	Lithium
MWt	Megawatts Thermal
Pu	Plutonium
U	Uranium
Zr	Zirconium

Intellectual Property

None

Total Number of Post-Doctoral Researchers

None