XeNRI: Xenon-135 Negative Reactivity Insertion

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Background


TREAT (left) and the HENRI prototype (right)

- The Transient Reactor Test (TREAT) Facility at Idaho National Laboratory (INL) uses transients, or short bursts of high power, to test nuclear reactor fuels and materials under non-normal and accident conditions. These tests ensure that fuels used in nuclear reactors will be safe, even during severe accidents. TREAT website and virtual tour.
- The Helium-3 Enhanced Negative Reactivity Insertion (HENRI) system was proposed to expand the capabilities of TREAT to be able to simulate a Reactivity Insertion Accident (RIA) by injecting a strong neutron absorber, He-3, into the core to shorten a transient. A HENRI prototype has been built and tested at Oregon State University. HENRI website and virtual tour.
- The density change of He-3 during a transient injecting is imperative to understand to be able to predict the behavior of the HENRI system.
- The XeNRI project was proposed to characterize the density changes of helium-3 in the HENRI system using xenon-135 and the OSU TRIGA reactor. Learn more at the XeNRI website.

Oregon State University

Project Results

Xenon-135 Breeding

Before using xenon-135, the gas first must be obtained. Xenon-135 is not naturally occuring and is radioactive, so it must be bred in a reactor by bombarding xenon-134 with neutrons. Calculations were done using MATLAB, and checked with a second code, which was developed for this project, BREED. These calculations found the density of xenon-135 over time depending on the initial density of xenon-134 and the flux of the reactor. Physical experiments will hopefully confirm that the density of xenon-135 reaches a desired amount using the TRIGA reactor. The latest release of BREED can be found here.

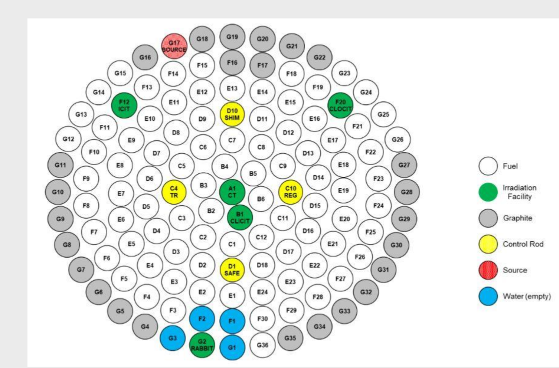
The BREED Userinterface

Helium-3 Energy Deposition

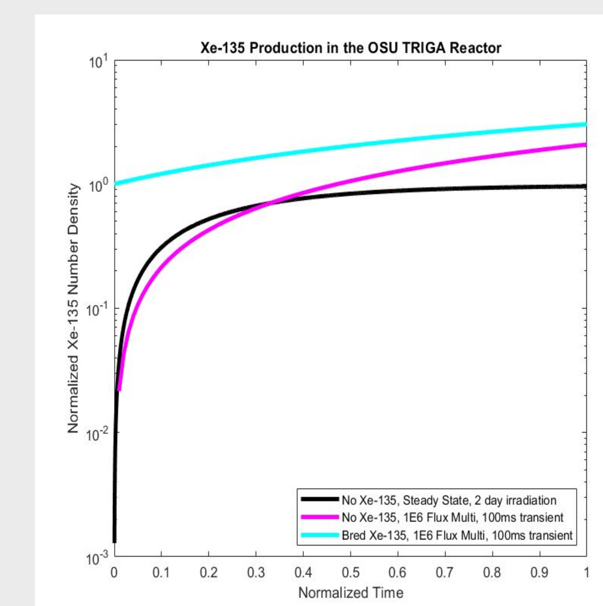
It is important to establish an understanding on how temperature and density will change to compare to that of xenon-135. This comparison will yield a better judgement on xenon's ability to characterize helium's behavior. Simulations were performed to determine the feasibility of using xenon-135 to characterize the density changes seen in helium-3. One of the primary simulations was executed through a program known as the Stopping and Range of Ions in Matter (SRIM). SRIM utilizes a Core and Bond methodology to calculate ranges and stopping powers in matter. Using SRIM, helium-3 was modelled as a "target matter" and the proton as the "incoming ion". SRIM outputs were manipulated to receive energy deposition per reaction. Furthermore, knowing the energy per reaction yields the temperature and density change in the system. SRIM provides a reliable output on the variation of thermal properties

Xenon-135 & Helium-3 Comparison

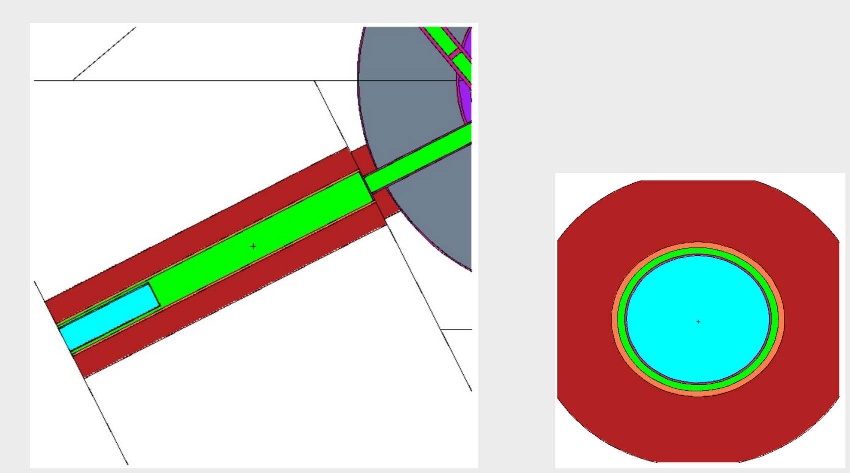
Utilizing MCNP, a comparison of xenon-135 and helium-3 performed in the TRIGA using the same physical properties. Using the the ratio of core criticality from the output file, the amount of reactivity in dollars was then calculated using the delayed neutron factor of the TRIGA core. These comparisons examined the effects at the A1, E7, and F2 positions.



A Map of the OSU TRIGA Core



Plot of Different Xenon-135 Breeding Conditions in the OSU TRIGA Reactor



Model of Xenon-135 Breeding Capsule in the OSU TRIGA reactor in MCNP

Xenon-135 Energy Deposition

MCNP is able to handle energy deposition and flux calculations through the use of Tallies. Using this and a complete model of the OSU TRIGA Reactor provided by the Radiation Center, the capsule was able to be inserted into Beam Port 4 (as seen above). Using these tallies and a flux multiplier to set the numbers to be equal to 1 MW operation, data was available to compare the effects of neutron bombardment on Xe-135 and the He-3 numbers found from SRIM. The only shortcoming of our model is the lack of accounting for photons. However, since the photons given off will be fairly high energy gamma rays and xenon is not a good gamma shield, the energy deposition due to photons can be considered negligible for these early models.

Conclusions and Future Work

- It is possible to breed Xe-135 in the OSU TRIGA reactor during both steady state and transient conditions.
- Helium-3 has a significant amount of energy deposition due to the proton released during the neutron absorption reaction, which may not be able to be replicated in xenon-135.
- Xenon-135's lower energy deposition makes it a great candidate as an alternative to helium-3 for the HENRI system.
- Going forward, more work needs to be done on the energy deposition in Xe-135 to determine if it will be able to characterize the density changes observed in He-3.
- Physical experimentation needs to be completed to validate the calculation and simulation performed.
- The MCNP model for energy deposition does not account for photons, so further models can be refined to account for them even though the additional energy deposited should be negligible

The Team website

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