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IEC Fusor Mobile Shielding Unit

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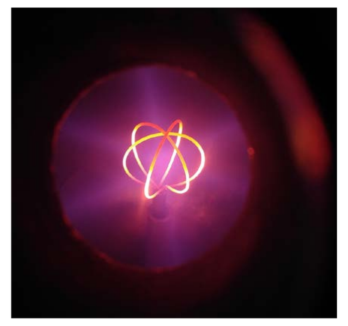
What is Fusion?

Nuclear fusion occurs when two lighter nuclei combine to form a new atomic nucleus. Upon this collision many bi-products may be created such as neutrons, gamma rays, and X-Rays. This process releases energy due to the conversion of mass to energy. Fusion has many important applications, including energy production, materials research, as well as the creation of medical and industrial isotopes. Many methods exist for achieving fusion, such as inertial electrostatic confinement, magnetic confinement, laser inertial confinement, and thermonuclear.



What is an IEC Fusor?

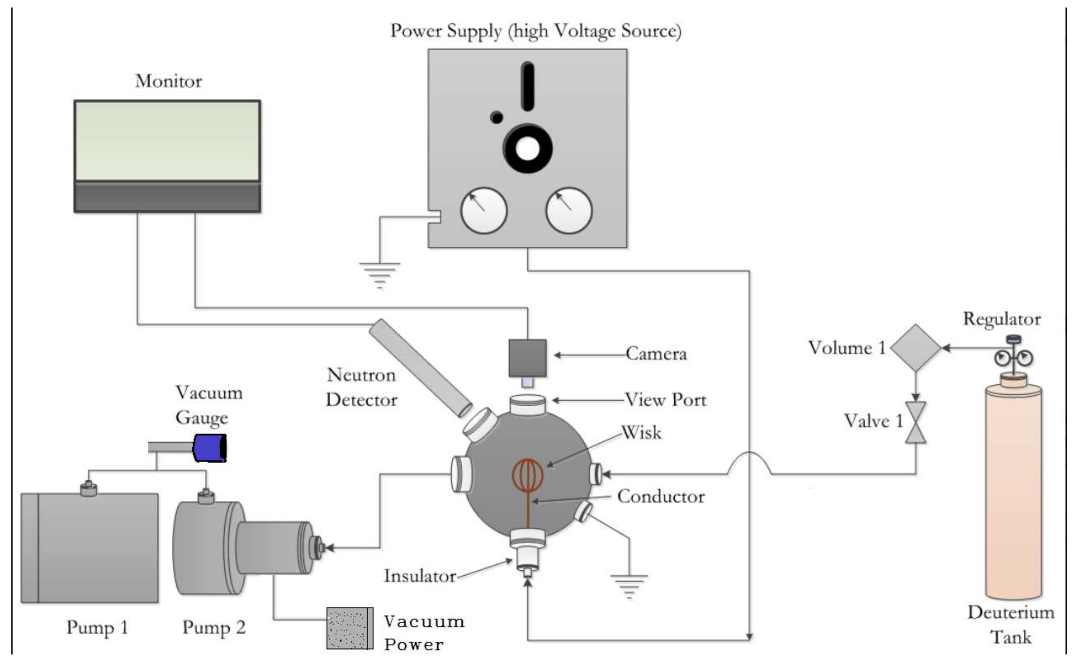
In order for nuclear fusion to occur between two like- charged particles, large Coulombic forces must be overcome. Essentially, the fusion reactants must be given enough energy to overcome the Coulomb barrier and allow the strong nuclear force to come into effect. In an IEC fusor, a strong electric field is generated in order to accelerate deuterium ions with enough energy to achieve fusion. A high vacuum environment is created in the reactor vessel to limit deuterium interactions with air molecules. Under these conditions, the positively charged deuterium nuclei move toward the negatively charged inner grid and undergo fusion, resulting in the production of new particles such as helium-3, tritium, and neutrons. The VCU Mechanical and Nuclear Engineering Department has a functional IEC Fusor, developed and built by previous senior design teams.

Project Objectives

- Adjust current IEC fusor design into a more compact and mobile form to allow for use by various faculty members and researchers as a neutron source for research and educational purposes
- Provide the user easy transportation of the shielding, fusor, and necessary components.
- Design radiation shielding to reduce radiation dose exposure in adherence with NRC dose limits.
- Design a sample holder for safe and effective material activation experiments
- Design a visualization system for observation of deuterium ionization and fusion from outside of the reactor shielding
- Create an operator's manual and user log to assist future operators with running the fusor.

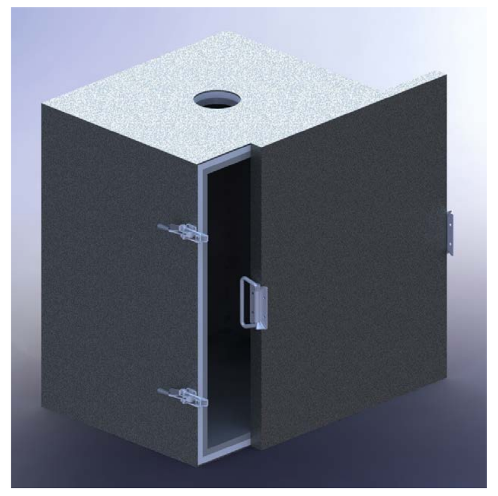
Constraints

- Cart must be large enough to house all required components, while being compact enough to fit through standard doorways
- Cart must be easy to maneuver, with a maximum of two people required for transportation
- Shielding unit must be optimized in terms of weight while conforming to NRC dose limits (100 mrem annual dose)



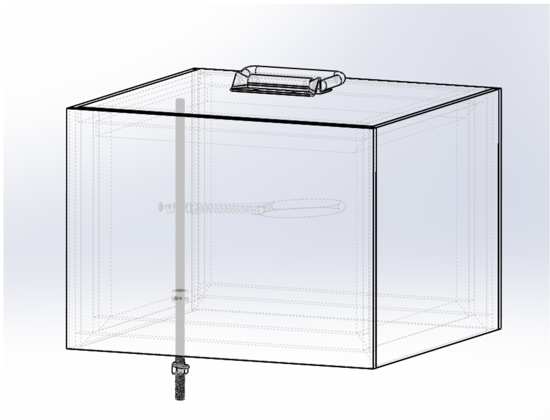
Shielding Design

In order to reduce the radiation exposure for operators of the fusor, a radiation shielding unit was constructed. This shielding unit is composed of concentric layers of high density polyethylene (HDPE), borated polyethylene (BPE), and lead in order to prevent neutrons and x-rays from reaching individuals around the fusor. Using the Monte Carlo n-Particle code to model the shielding unit, HDPE, BPE and lead thicknesses of ½ in, ½ in, and ⅛ in, respectively, provide minimum material dimensions in order to adhere to NRC dose limits.



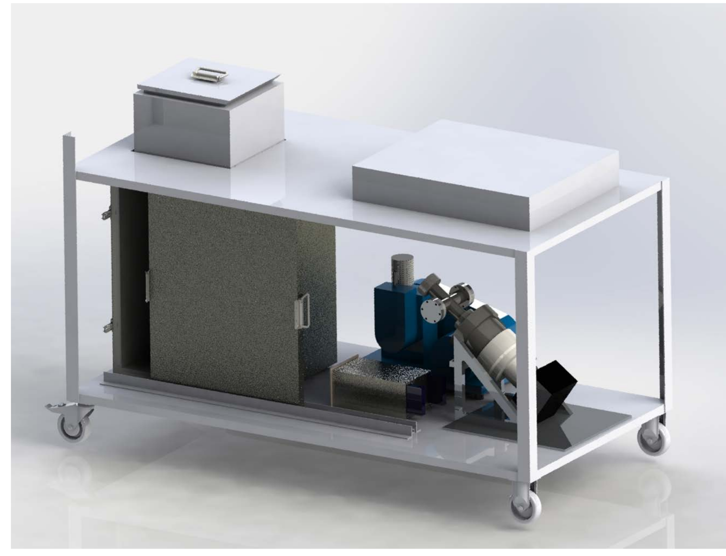
Sample Holder Design

The sample holder allows for the irradiation of specimens contained within vials. These vials rest in a ring stand of adjustable height. A hole in the main reactor shielding allows for a neutron beam to reach materials for irradiation experimentation. A smaller shielding unit also surrounds the sample holder, and has similar thicknesses of materials as the main shielding.



Cart Design

A cart was acquired for easy transportation of all fusor components. This allows for the fusor to be operated in different labs, without complete disassembly for transportation. The power supply and viewing monitor are located on the top level of the cart, as they require constant adjustment by the fusor operator. The remaining fusor components are located on the bottom level of the cart. The cart was also modified to allow for placement of the sample holder and component wiring.



Visualization System Design

In order to monitor conditions inside of the reactor vessel from outside of the shielding unit, a camera was placed in front of the fusor viewport. This camera was connected to a Raspberry Pi 3 Model B, with the output displayed on an adjustable monitor attached to the cart. This allows for viewing and adjustment of fusor conditions from a safe distance outside of the shielding unit.

Acknowledgements

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