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Inertial Electrostatic Confinement Fusor

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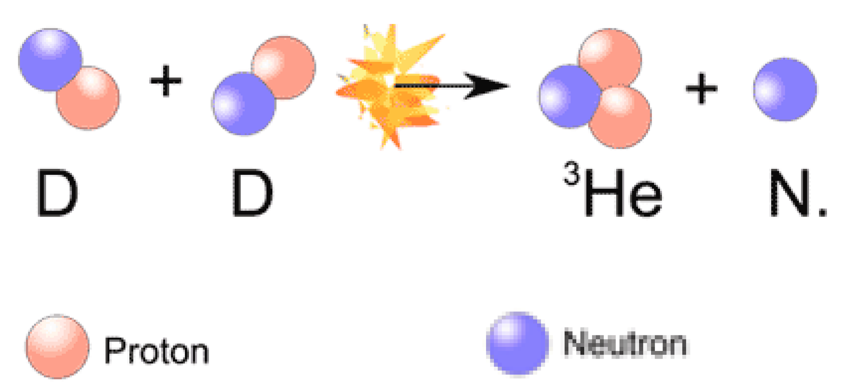
MECHANICAL AND NUCLEAR

Inertial Electrostatic Confinement Fusor

CAPSTONE DESIGN EXPO 2015

What is Fusion?



Fusion is the process in which two atomic nuclei fuse to release energy in the form of neutrons. Our fusion experiments use deuterium gas (D or ^{2}H), an isotope of hydrogen with one neutron and one proton. Fusion is achieved in a deuterium fusion reactor by injecting deuterium ions into the reactor, where a negatively charged grid sits. A large potential difference causes the ions to isotropically accelerate towards this grid, causing deuterium collisions and generating neutrons.

Our System

The inertial electrostatic confinement (IEC) fusion reactor (fusor) operates by pulling an ultra high vacuum inside a pressure vessel. Within the pressure vessel is a cathode grid that is energized with a negative electrical potential. Once the cathode is energized and the pressure in the chamber is lowered to an optimal operating point, deuterium is introduced into the system. The deuterium ions flood to the center of the chamber, causing fusion reactions. The fusor employs a data acquisition system to monitor deuterium flow rates, vacuum levels, and the power supplied to grid inside the fusor. To measure the intensity of the fusion reactions, a piece of silver foil is integrated in the fusor's shielding, allowing it to be irradiated. Because the silver decays by means of beta radiation, the intensity of the reactions can be determined by measuring the rate of decay with a Geiger-Mueller detector.


Figure 1: Fusion Reaction

Shielding

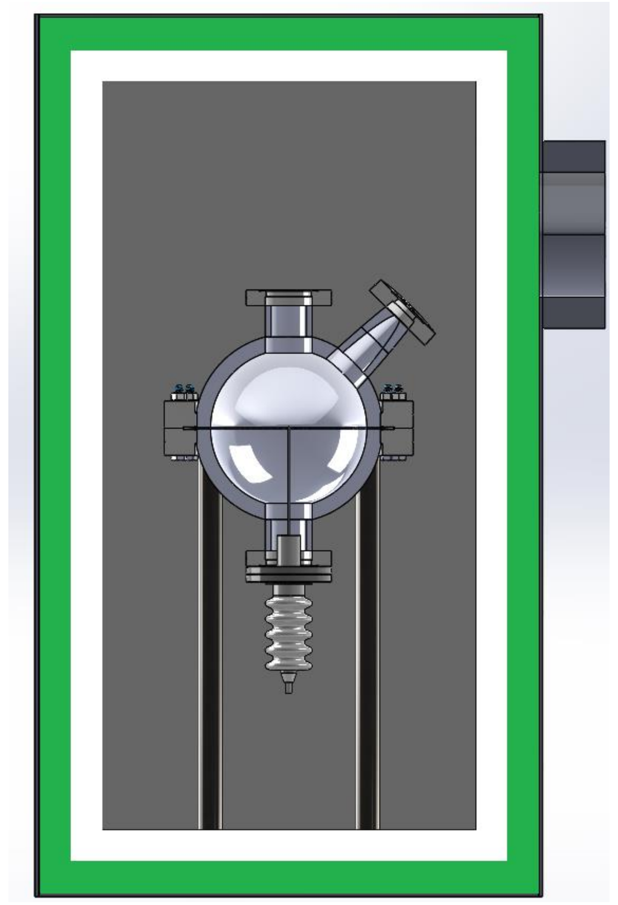


Figure 4: Model of Fusor and Shielding

Because the D-D fusion reaction results in the production of neutrons and X-rays, shielding is necessary to protect users from the radiation produced by the fusor. A Monte Carlo n-Particle (MCNP) model was developed to calculate the necessary shielding. The shielding includes layers of HDPE and BPE that will account for neutrons, as well as beta particles, and a layer of Lead to shield x-rays.

Shielding Layers (left):
1. Outer: Lead, painted black
2. Middle: Borated Polyethylene (BPE), green
3. Inner: High Density Polyethylene (HDPE), white

Iterative Grid Testing

In the previous year, the only grid tested was a three loop tungsten grid with a two inch diameter. This year, a number of different grids were constructed using four different materials, each with six different geometries. The purpose of these alternative constructions is to determine if the different materials or geometries would reduce the number of surface emissions, which would increase the efficiency of the reactor.

Grid Materials:	Grid Diameters:	Grid Geometries:
1. Tungsten	1. 1 inch	1. 2 Loop
2. Titanium	2. 2 inch	2. 3 Loop
3. Molybdenum	3. 3 inch	
4. Nickel		


Figure 3: Actual Grid Shape

Computational Modeling

One of the potential uses of the fusor will be to irradiate materials and see how they behave after certain levels of both fast and thermal neutron exposure. To reduce the amount of time and resources spent testing, a computational model using XOOPIC, a particle interaction software, was developed to model the fusor. Using this, the independent variables can be manipulated to determine the necessary operating conditions to reach the materials testing specifications.

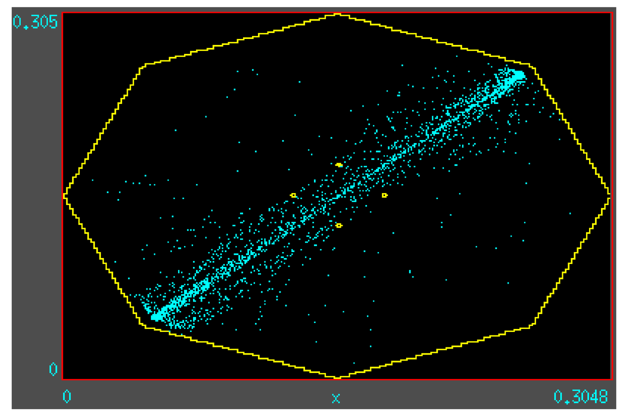


Figure 4: Simulation of Ions Within the Fusion Reactor

Future Work

The fusor design project started as a means to build a neutron generator for the Mechanical and Nuclear Engineering department at VCU. We hope that the fusor project will be continued by successive Senior Design teams.

The fusor is a very versatile device, and could be used by the next team for:
1. Materials embrittlement testing
2. Neutron activation
3. Developing an active cooling grid
4. Parametric evaluation of efficiency vs. grid materials and geometry


Figure 5: Actively Cooled Grid Design

Special Thanks

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Newport News Shipbuilding
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