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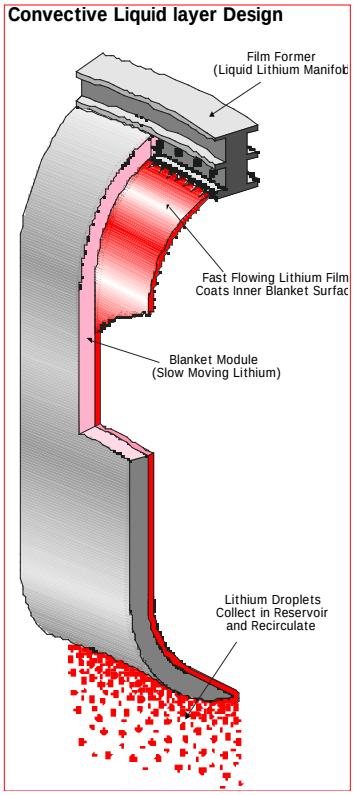
Fusion technologies lead to attractive energy sources

As fusion energy research advances toward engineering the world's first fusion power system, establishing the fusion technology base moves to the forefront. Fusion technologies focus on the long-term technology base needed for fusion to achieve its full potential as an environmentally and economically attractive energy source. The key fusion technologies include:

- **Plasma and fusion energy chamber technology (APEX)**
- **Remote handling**
- **Safety and environment**
- **Tritium systems**

APEX (Advanced Power Extraction)



Liquid layer concept
Drawing courtesy University of California, Los Angeles

The APEX initiative explores innovative concepts that substantially improve the vision for an attractive and competitive energy system. The challenge to fusion technologists is achieving high power density with high thermal efficiency loads while satisfying all fusion power technology functional requirements (e.g., tritium self-sufficiency) and maximizing reliability, maintainability, safety, and environmental attractiveness. An innovative concept under investigation is liquid walls.

Liquid walls could shield structures and thereby offer a solution for safety and environmental challenges. Liquid walls would reduce both the radioactive hazard and the waste volume, while increasing the lifetime of components. Systems reliability may be also improved since liquid walls eliminate vulnerable structures (e.g., first walls) that require frequent maintenance.

For liquid walls the heat transfer is intimately connected to the fluid flow characteristics of the liquid. Modeling of this behavior is a challenging problem in the cutting edge of scientific disciplines of turbulence modeling, two-phase flow modeling, hydrodynamic stability, magnetohydrodynamics, and radiation transport.

Remote handling

The development of sophisticated remote handling systems are key for maintenance, repair and modification of fusion power stations. Remote handling technologies are also necessary for system diagnostics to measure experimental results.

The removal and replacement of components is critical to assure the continued integrity of fusion systems. Accomplishing these tasks requires cutting welded joints, unfastening bolted flanges and couplings, and disconnecting water and gas pipes, as well as lifting and maneuvering of extremely heavy components weighing several tons.

The long term goals relative to this enabling technology is to develop a remotely deployed, laser based metrology/viewing system to inspect plasma facing components and other first wall components, and to develop the equipment and techniques to remotely weld and cut the large structures that comprise the plasma chamber.

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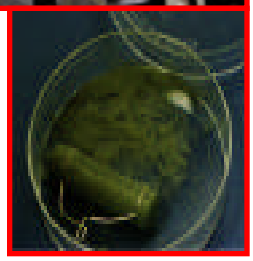
Superior safety and environmental features

Fusion's safety and environmental advantages make it an attractive option for creating an energy infrastructure to meet the economic and environmental goals of the 21st century. Current safety research and development, as well as analysis activities are aimed at providing --

- Experimentally verified methodologies for analysis, assessment, and resolution of safety and environmental issues;
- A technical basis for achieving the best features in the design of fusion facilities; and
- A technical foundation and recommended strategies for licensing and decommissioning of fusion stations.

Both magnetic and inertial fusion energy technologies emphasize an integrated approach to addressing environmental and safety concerns. Experiments are performed to understand the behavior of the major sources of radioactivity and the dominant energy sources in each chamber approach. These experiments address issues related to activation, tritium uptake, chemical reactions and dust/debris transport. These data are used to develop methodologies for analysis, assessment and resolution of key safety and environmental issues with the aim of improving the design of the particular fusion concept.



Understanding the chemical reactivity behavior of different forms of beryllium and the safety limits on its use as a plasma facing component.

The development of fusion energy systems offers the opportunity to minimize the problems associated with radioactive waste. Although fusion is a nuclear process, it differs from the fission process in that there is no radioactive by-product from the fusion reaction – only helium gas and a neutron. However, neutrons from the fusion reaction can produce some radioactivity in the surrounding systems.

Thus, the major focus environmentally for fusion is to reduce the volume of radioactive waste by reducing the long-lived neutron activation level of the in-vessel components of a fusion power system and potentially recycling and reusing these components. In inertial fusion, recovery and recycle of hohlraum materials in indirect drive targets is also important.

Tritium systems

Tritium is a relatively benign radioactive element with a moderate half-life of roughly 12 years. The overarching goal of the tritium systems element of the enabling technology program is to develop safe and efficient tritium systems. The following research areas are aimed at achieving this goal:

- Establish and implement technologies that effectively process tritium needed in burning plasma experiments;
- Establish processing technologies that avoid the formation of tritiated water and develop technologies for cost-effecting processing of dilute tritiated water;
- Develop technologies for removing and processing tritium from reactor materials;
- Provide tritium technologies needed for developing other fusion-related technologies such as plasma facing components, fueling, and vacuum vessel; and
- Continue to demonstrate that tritium can be safely managed.