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# THE INTERESTING POSSIBILITIES OF FUSION-FISSION*

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## SUMMARY

In a world economy highly sensitive to increasing energy demands, it is vital to investigate all viable combinations of energy producing methods. The fusion-fission hybrid is such a combination. We recognize the ultimate "pure" fusion reactor but contend that a step along the way may be fusion-fission. It may decrease the time to a demonstration reactor since the plasma characteristics necessary to achieve fusion-fission are significantly less than those for pure fusion power.

A fissile blanket in a fusion reactor could be designed for the following primary purposes:

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a) Neutron multiplication

The fissionable material may be used as neutron multiplier (more efficiently than Be) in order to increase the tritium breeding ratio.

b) A breeder of fissionable material for fission reactors

With the long fuel doubling time now postulated for the LMFBR (> 30 years) versus short doubling time for fusion-fission, the latter may better keep up with growth of electrical power requirements.

The fissile blanket can be designed to be a very effective breeder. It can breed $^{239}Pu$ from natural (or depleted) uranium or $^{233}U$ from thorium, with a relatively short "doubling time." The fissile blanket is designed subcritical and has low power density alleviating the loss of coolant problem

c) Energy amplification in a power producing reactor

The fissile blanket increases the energy yield per fusion to as much as 1000 MeV per 14 MeV source neutron which increases power output and thermal efficiency. In such a reactor, breeding of fissionable material and adequate tritium breeding ratio can be retained.

d) Intermediate target in the development of fusion reactors

Since the Lawson criterion decreases in inverse proportion to the blanket energy amplification, it is conceivable to build such a system at a relatively early stage of fusion development. Hybrid power plants with smaller physical size, lower first wall loading, lower B fields, and lower $\beta$ for the same power are possible.

The choice between fusion-fission as a fuel factory producing fuel for fission reactors or as a power producing reactor is not clear. Some pluses and minuses are:

| Fuel Factory | Power Producing Reactor |
|---|---|
| No requirement to run all the time | Must have ~ 80% duty factor |
| Can fuel n reactors | |
| Disassembly for fuel recovery could be difficult | Time to disassembly may not be a significant parameter |
| Requires fusion plant and fission plant so costs could be high | Requires only one plant |
| Fuel transport required | Fuel burned in situ |
| Could be remotely located | Must be near urban centers |
| Low neutron wall load | Low neutron wall load |
| Eases Lawson criterion | Eases Lawson criterion |
| The fission reactor part has already passed regulatory tests | Must pass the AEC regulatory tests in total |
| Need not be a net power producer | Must have positive power output |

In a cooperative effort, the Lawrence Livermore Laboratory (LLL) and Pacific Northwest Laboratories (PNL) have undertaken a series of studies encompassing fissile blankets ranging from thermal to fast. LLL has concentrated on the fast spectrum, and PNL on the thermal lattice. Both use the same basic blanket geometry, and both use energy amplification for a power producing reactor as the primary goal.

The particular blanket used is based on a mirror fusion reactor developed by LLL. In this design, every effort has been made to use existing technology in order that research and development be kept to a minimum. The blanket region is based on a geodesic geometry. Some 320 triangular prisms, called modules, are used to form a nearly spherical blanket. The blanket region performs several functions. They include:

- Multiplication of the fusion neutron power by a factor of 7 to 50
- Production of fissile fuel (Pu)
- Production of fusion fuel ($^3H$)

For the PNL approach, the fissile blanket consists of a number of regions. An inner region (∿ 8 cm thick) consists of depleted $UO_2$ stainless-steel clad fuel plates cooled with helium. This converter region performs several functions. It converts, by means of $^{238}U$ fission, n,2n and n,3n reactions the 14 MeV fusion source neutrons to neutrons of lower energy and breeds high quality fissile fuel. This region is followed by a thin (∿ 2 cm) lithium, stainless-steel region cooled with helium. This inner tritium breeding region performs two functions. It breeds tritium by neutron absorption in lithium, and it shields the converter from lower energy neutrons which would degrade the quality of the fissile fuel bred in the converter and excessively increase the neutron multiplication through $^{239}Pu$ fissions in the converter. The central region of the blanket, the fission lattice, is the region where the bulk of the thermal energy is produced and energy multiplication of approximately 50 takes place. It consists of a modified HTGR gas cooled lattice 150 cm thick. Slightly enriched (∿ 1%) uranium dioxide fuel and an expanded fuel lattice pitch (∿ 3.38 cm) are used. Exterior to the lattice are a graphite reflector region and an outer tritium breeding region. The total blanket is 2 m thick surrounded by a 1 m thick radiation shield.

For the LLL fissile blanket, a thin (∿ 20 cm) inner region of natural uranium is used to maximize the fast fission of $^{238}U$. Energy multiplication factors of the fusion neutron power of 7 to 14 appear achievable. Over 80% of the fission reactions in this blanket are $^{238}U$ fast neutron fissions. Such blankets operate at low power density and appear capable of high fuel burn-up (> 10%) resulting in a fuel lifetime of 10 years or more. The total blanket thickness is < 1 meter followed by a ∿ m thick shield. Since this blanket is fueled with natural uranium, it has no fissile fuel breeding requirements. Furthermore, since high neutron energies are utilized, high uranium resource utilization can be realized without requiring fuel reprocessing. Achievable fuel burn-up appears to be limited by radiation damage to cladding and structure and not by degradation of neutronic performance.

The fission lattices in the blankets of these two hybrid systems are designed to be subcritical ($k_{eff} < 1$) in all stages of operation, the fast spectrum blanket having a lower $k_{eff}$ than the thermal spectrum. Attention has been paid to the danger of an accidental release of radioactive materials from a hybrid. A basic engineering design goal for the hybrid is to require no emergency cooling in the event of loss of coolant.

The detailed engineering problems due to the introduction of fissile material into the blanket are still unexplored. They will cause some complexity in reactor design. However, the potential benefits of the fusion-fission hybrid revealed by studies to date provide a strong impetus for continued research in this area.

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