STATUS OF FUSION REACTOR BLANKET DESIGN*

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CONF-860652--21

DE86 014527

February 1986

* Work supported by the U.S. Department of Energy, Office of Fusion Energy.

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The recent Blanket Comparison and Selection Study (BCSS)[1], which was a comprehensive evaluation of fusion reactor blanket design and the status of blanket technology, serves as an excellent basis for further development of blanket technology. This study provided an evaluation of over 130 blanket concepts for the reference case of electric power producing, DT fueled reactors in both Tokamak and Tandem Mirror (TMR) configurations. Based on a specific set of reactor operating parameters, the current understanding of materials and blanket technology, and a uniform evaluation methodology developed as part of the study, a limited number of concepts were identified that offer the greatest potential for making fusion an attractive energy source.

It is extremely important when interpreting the conclusions of this study, as well as all other design studies, to carefully consider all assumptions and design criteria that influence specific conclusions. The general reactor design guidelines for the reference tokamak and tandem mirror reactors are given in Table 1. Although these reference parameters are regarded as reasonable and appropriate at this time, they may indeed be subject to change with advances in fusion technology. Those parameters that strongly influence the operating limits of the leading blanket concepts have been identified. An example is the importance of magnetic field strength on the performance of self-cooled liquid metal blankets. An improvement in plasma confinement, viz., β, which could translate to a reduction in the toroidal magnetic field, would substantially reduce the MHD effects. Likewise, an increase in the magnetic field would exacerbate the MHD problems. However, many aspects of the blanket designs are relatively insensitive to many of the general reactor parameters. For example, tritium recovery constraints for solid breeder blankets are not sensitive to magnetic field or first wall erosion rates.

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TABLE 1: Reactor Guidelines from BCSS

	Tokamak	TMR
Reactor Design Basis	STARFIRE	MARS
Peak magnetic Field, T	10	5
Neutron Wall Load, MW/m^2	5	5
First Wall Heat Flux, W/cm^2	100	5
First Wall Erosion, mm/y	1	0.1
Dose to TF Coils, rads	10^{10}	10^{10}

Of the large number of blanket concepts considered in the BCSS, the nine concepts that were selected for evaluation in detail are listed in Table 2. The primary constraints and major uncertainties associated with each of these concepts were identified. Based on the systematic and comprehensive evaluation performed, the leading concepts are indicated in Table 3. It was generally concluded that major improvements to the other concepts, as a result of further development, would likely be applicable to one or more of the leading concepts. However, it was also recognized that major changes in the criteria might lead to different conclusions.

TABLE 2: Nine Blanket Concepts Evaluated in Detail in the BCSS

Li/Li/V	Li_2O/He/FS
Li/Li/FS[a]	$LiAlO_2$/He/FS/Be
LiPb/LiPb/V[a]	$LiAlO_2$/H_2O/FS/Be
Li/He/FS	$LiAlO_2$/NS/FS/Be
FLIBE/He/FS/Be	

(FS: Ferritic Steel, NS: Nitrate Salt)

[a]Not rated R=1 for tokamak configuration.

TABLE 3: Four Leading Concepts Recommended in the BCSS to Provide a Focus for Future Blanket R & D

Li/Li/V	- Overall top rated concept for tokamak, marginally superior for TMR.
LiPb/LiPb/V	- High ranking for TMR only.
Li_2O/He/FS	- Top rated solid breeder.
Li/He/FS	- Rates well below top three. - Only marginally superior to other concepts. - Unique feasibility issues.

* Should consider ternary solid breeder ($LiAlO_2$) concepts as backup to Li_2O.

With this as a background, the primary objectives of more recent blanket design efforts have been to improve the attractiveness of fusion by one or more of the following:

- Evaluation of enhanced blanket performance for leading concepts that result from an improved data base or changes in design guidelines because of improved reactor design/performance.

- Further attempts to improve blanket performance of leading concepts by improved design or analysis.

- Continued development of improved or innovative designs or concepts using the BCSS evaluation methodology as a reference for comparison.

The major efforts in the last two years for improving fusion reactor blanket performance can be classified into the following areas[2,3]:

- Improvements in self-cooled liquid metal concepts, particularly lithium, provided by a better understanding and analysis of the MHD and compatibility issues; e.g., extensive use of electrically insulated walls.

- Simplification of solid breeder concepts by innovative tritium recovery scenerios.

- Improved economic performance by incorporating substantial amounts of beryllium or other candidate materials as energy multipliers.

- Improvement in the energy conversion efficiency of helium-cooled designs by utilization of higher temperature structural materials such as vanadium.

- Improvement in blanket performance by utilization of the perceived advantages of vanadium as a first wall/blanket structural material.

- Expanded use of reduced activation materials, e.g., modified ferritic steels or vanadium alloys, and partial blanket replacement to minimize radioactive waste management requirements.

- Innovative concepts that maintain the design simplicity of self-cooled liquid metal concepts, but which utilize an alternate breeder/coolant, viz., Flibe.

Specific concepts in which significant effort has been expended since completion of the BCSS are listed in Table 4 (breeder/coolant/structure/multiplier).

TABLE 4: Blanket Concepts that have Served as a Focus for Recent Blanket Design Studies

Li/Li/V	(2)
Li_2O/He/V/Be	(2)
Flibe/Flibe/V	(2,3)
Li/He/V/Be	(3)
LiPb/He/FS/Be	(3)
Flibe/He/V/Be	(3)

This paper describes the features of the "improved" concepts as well as the primary uncertainities and constraints associated with each.

References

1. D. L. Smith, et al., "Blanket Comparison and Selection Study - Final Report," Argonne National Laboratory, ANL/FPP-84-1. (September 1984.)

2. C. C. Baker, et al., "Tokamak Power Systems Study - Fiscal Year," ANL/FPP-85-2. (October 1985.)

3. J. D. Lee, et al., "Mini-Mars Conceptual Design Study," UCID-20559. (December 1985.)