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COST STUDY OF THE ESPRESSO BLANKET FOR A TANDEM MIRROR REACTOR

A. Rene Raffray,* Myron A. Hoffman,** and Thomas Gas ins

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*University of California, Center for Fusion Engineering, Los Angeles, CA
**University of California, Davis, CA

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A. R. Raffray, M. A. Hoffman, and T. Gaskins

A detailed cost study of the ESPRESSO blanket concept for the Tandem Mirror Fusion Reactor (TMR) has been performed to complement the thermal-hydraulic parametric study and to help narrow down the choice of parameters for the final design.[1] The ESPRESSO blanket consists of a number of structurally independent ring modules. Each ring module is made up of a number of mutually pressure-supporting canisters containing arrays of breeder tubes. Two separate helium coolant flows are used: a main flow to cool the tube bank and a cooler first wall flow.

The cost study concentrated on a control volume consisting of a ring module with its immediate piping system and the corresponding solenoidal coil. The results were multiplied by the number of ring modules to obtain the cost of the TMR central cell. Figure 1 shows half of the cross section of a typical ring module assembly.

A computer code was developed[1] to size the magnet, blanket, and piping components and to evaluate the central-cell contribution to the cost of electricity. The sizing of the magnets was done using a model which solves a set of non-linear equations for specified values of the coil inner radius, the peak centerline magnetic field, the magnetic field ripple and the coil operating and critical currents to obtain the coil dimensions. The costs of the coils, blanket components and piping were then determined based on the volumes of each component. The central cell contribution to the cost of electricity at the busbars was then calculated from the following equation:

$$C_{BUS(CC)} = \frac{C_{CAP}\,(FCR) + C_{O\&M} + C_{RR} + C_{DIS}}{(8760\ hrs/yr)\ (P_E - P_p)\ A}$$

where: C_{CAP} = total capital cost of the central cell components,

FCR = annual fixed charge rate,

$C_{O\&M}$ = annual operating and maintenance cost

C_{RR} = annual scheduled component replacement cost,

C_{DIS} = annual disposal cost for irradiated components which have been replaced,

P_E = total electrical power produced by the central cell,

P_p = total pumping power associated with the central cell up to and including the ring headers,

A = availability

Two cases were finally chosen for detailed study based on their attractive overall potential: natural lithium oxide as breeder material with no neutron multiplier (Case I), and gamma-lithium aluminate as breeder material with beryllium as the multiplier (Case IV of Ref. 1).

Typical cost results combined with the thermal-hydraulic limits are summarized in Figure 2 for the $LiAlO_2$/Be case. The values of $C_{BUS(CC)}$ have been normalized by the minimum $C_{BUS(CC)}$ within the design window, which was 41 mills/KWH at a wall loading of about 3.3 MW/m^2. Because of the desirability of keeping the pumping power ratio,, $PPR_{el} = P_p/P_E$, (based on the electrical power) under about 3%, the design point will probably be closer to a neutron first wall loading of about 3.0 MW/m^2, as indicated on Figure 2. For the Li_2O case, the corresponding minimum $C_{BUS(CC)}$ within the design window was found to be 31 mills/KWH at a wall loading of about 2.4 MW/m^2.

If the central cell contribution to the cost of electricity, $C_{BUS(CC)}$, is assumed to be typically about a fourth to a third of the total busbar costs, then $C_{BUS(CC)}$ for Blanket Options E (Li_2O) and F ($LiAlO_2$/Be) of the BCSS study[2] would be between 23 and 30 mills/KWH. This means that the Li_2O ESPRESSO design is comparable in cost to the BCSS Blanket Option E, in spite of beng thicker than the BCSS blanket due to the lower breeder volume fraction of the ESPRESSO tube array. However, the $LiAlO_2$/B ESPRESSO design appears to be somewhat more expensive than the comparable BCSS Blanket Option F, because the disadvantage associated with the thicker ESPRESSO tube-bank blanket concept is felt more strongly due to the high cost of the 30% enriched $LiAlO_2$. Since the cost estimates for fusion reactors are all still rather approximate, these results are interepreted to indicate that the ESPRESSO blanket has the potential to be a cost-effective concept with some refinement and optimization.

References

1. A. R. Raffray, "Design and Cost Study of the ESPRESSO Blanket Concept for the Tandem Mirror Fusion Reactor", Doctor of Engineering Dissertation, Department of Mechanical Engineering, University of California, Davis, CA 95616, October 1985.

2. M. A. Abdou et al., "Blanket Comparison and Selection Study", Final Report, Fusion Power Program, Argonne National Laboratory, Argonne, IL, ANL/FPP-84-1, September 1984.

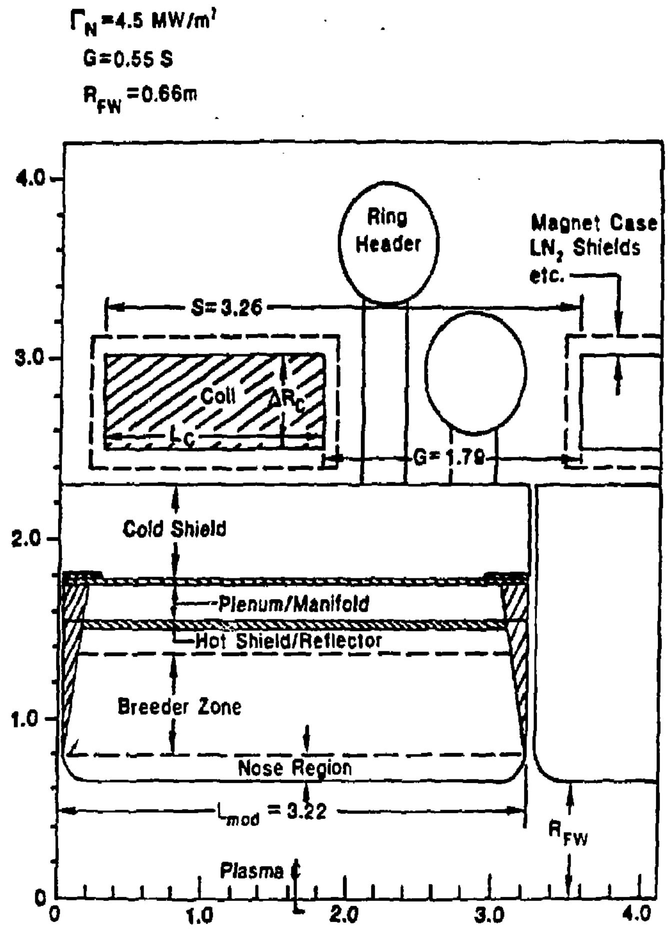

Figure 1 - Typical Ring Module and Coil Cross-Section
(with dimensions shown in meters)

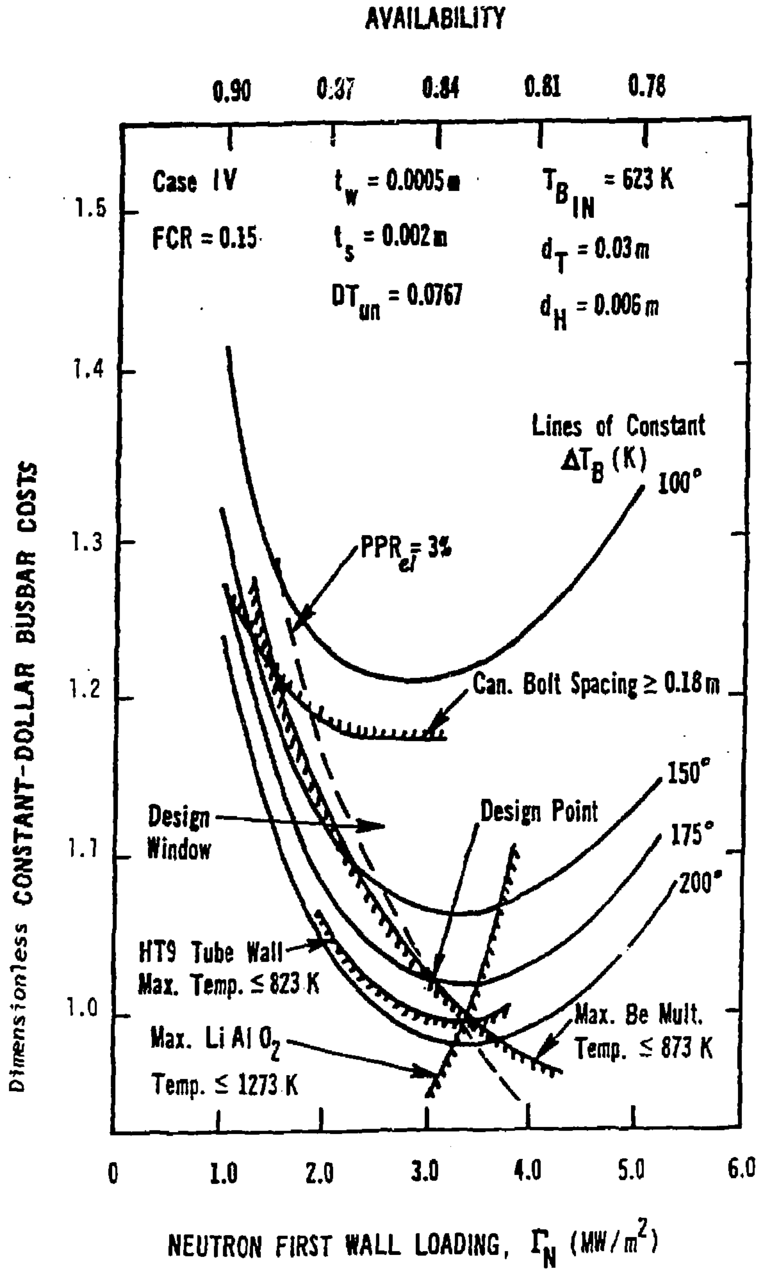

Figure 2 - Dimensionless Central Cell Contribution to the Busbar Costs for Different Values of the Main-Flow Bulk Temperature Rise.