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THERMAL HYDRAULIC STUDY OF THE ESPRESSO BLANKET FOR A TANDEM MIRROR REACTOR

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THERMAL-HYDRAULIC STUDY OF THE ESPRESSO BLANKET FOR A TANDEM MIRROR REACTOR

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This paper deals primarily with the thermal-hydraulic design and some critical thermomechanical aspects of the proposed ESPRESSO blanket for the Tandem Mirror Fusion Reactor.¹ This conceptual design was based on the same physics as used in the MARS study.²

As shown in Figure 1, the proposed design includes a number of mutually pressure-supported canisters forming a ring module. Each ring module is completely independent with a tapered circular end-plate (not shown in the figure) at each end and a cylindrical back support which together take the pressure load of the 50 atm helium coolant. Each canister contains an array of breeder tubes in the breeder section and of steel rods in the hot shield section. Two separate helium coolant flows are used: a cooler first-wall flow keeping the first wall temperature and stress limit at an acceptable level, and a main coolant flowing over the tube bank with the canister performing as a two-pass crossflow heat exchanger.

A computer code was developed to perform self-consistent calculations of the geometry, first wall stresses and canister thermal-hydraulic parameters. The neutronic data used as input was obtained from three-dimensional Monte Carlo computations. The design code also includes a simple steam power plant model to calculate the steam cycle thermal efficiency and the electrical power produced, as well as a cost subroutine for estimating the central cell contribution to the cost of electricity.

Two different breeder/neutron multiplier configurations were finally chosen for detailed study based on their attractive overall potential:¹ natural lithium oxide with no multiplier (Case I) and 30% enriched gamma-lithium aluminate with a beryllium multiplier (Case IV).

In the calculations, the code first determined the canister first-wall radius based on the maximum allowable first-wall stress (for a specified maximum temperature). The optimum breeder tube diameter was then selected to give the maximum 3-D breeder volume fraction. The main-flow inlet temperature was set according to a minimum temperature constraint for each breeder material (chosen to keep the tritium inventory acceptably low). This in effect reduces the number of independent parameters to two, namely the neutron first wall loading, Γ_N , and the main-flow bulk temperature rise, ΔT_B (or equivalently, the outlet bulk temperature). The effect of these two variables on the pumping power ratio (PPR_{e1} , expressed as a percentage of the electrical power produced by the central cell), the maximum breeder temperature and the maximum multiplier temperature (if applicable) was investigated for the two chosen configurations.

Figure 2 summarizes the results for the $LiAlO_2/Be$ case. The permissible design region is bounded by the maximum allowable $LiAlO_2$ and Be temperature constraints. Basically, it is desired that the outlet bulk temperature be as high as possible so as to maximize the steam cycle efficiency. At the same time, PPR_{e1} must be kept to a reasonable level (about 3%). As shown on Figure 2, the design point based on these considerations is at a wall loading of about 3.0 MW/m^2 with a main-flow bulk temperature rise of 173 K (resulting in an outlet helium temperature of 796 K).

Analogous results for the Li_2O case show that the design point corresponds to a wall loading of about 2.3 MW/m^2 and an outlet bulk temperature of 819 K with a PPR_{e1} of only about 2%. Thus, the Li_2O case appears superior based on the lower PPR_{e1} and higher outlet helium

temperature (leading to a higher steam power plant efficiency). However, the final choice between the two cases must be based on a cost study; this cost study is described in Ref. 1 (and is to be published in a separate paper).

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, California 95616, October 1985.
2. "Mirror Advanced Reactor Study (MARS)", Final Report, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-53480, July 1984.

Figure 1 Ring Module Assembly

Figure 2