

## WATER-COOLED LIQUID AND SOLID BREEDER BLANKET

## CONCEPTS

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The Blanket Comparison and Selection Study (BCSS), led by Argonne National Laboratory, is conducting comparative evaluations of candidate blanket concepts for tokamak and tandem mirror reactors. This paper addresses the water-cooled concepts; others are discussed in separate papers at this conference.

Four concepts have been evaluated: (1) lithium oxide breeder ( $\text{Li}_2\text{O}$ ) with and without beryllium neutron multiplier ( $\text{Li}_2\text{O}/\text{H}_2\text{O}$ ,  $\text{Li}_2\text{O}/\text{H}_2\text{O}/\text{Be}$ ); (2) ternary oxide ceramic breeder ( $\gamma\text{-LiAlO}_2$ ) with beryllium neutron multiplier ( $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Be}$ ); (3)  $\gamma\text{-LiAlO}_2$  with lead neutron multiplier ( $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Pb}$ ); and (4)  $^{17}\text{Li}\text{-}^{83}\text{Pb}$  breeder without a separate neutron multiplier ( $\text{LiPb}/\text{H}_2\text{O}$ ). Candidate structural materials are austenitic stainless steel (PCA), ferritic steel (HT-9), and vanadium alloy (V-15Cr-5Ti). The pressurized water coolant is assumed to be at  $280^\circ\text{C}$  inlet,  $320^\circ\text{C}$  outlet, and 15.2 MPa design pressure.

For the  $\text{Li}_2/\text{H}_2\text{O}$  and  $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Be}$  concepts, key issues in design approach selection are basically the same: tritium release from the breeder; tritium permeation into the coolant; breeder-to-structure interface control; tritium breeding ratio (TBR); reliability against leaks; breeder fabrication and configuration. To maximize TBR, a breeder-outside-tube (BOT) approach has been selected, with the coolant contained in small-diameter tubes -- double-walled (DWT)

to increase reliability -- surrounded by breeder. The breeder is fabricated in sphere-pac configuration, a graded mix of 100% dense spherical particles of three different diameters. This permits adequate tritium release and predictable breeder-to-structure thermal conductance. Tritium permeation into the water coolant is a major concern: recent experiments indicate solid breeders may release diatomic tritium as the dominant specie. Adequate tritium removal rates must be provided and coolant tritium contamination must be maintained at acceptably low levels. This may require both effective barriers against tritium permeation (oxides) and a means for rapid oxidation of the tritium within the blanket.

The preliminary reference design for the  $\text{Li}_2\text{O}/\text{H}_2\text{O}$  concept (tokamak version) is shown in Figure 1(a); designs for the  $\text{Li}_2\text{O}/\text{H}_2\text{O}/\text{Be}$  and  $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Be}$  concepts are similar. HT-9 ferritic steel is the reference structural material. The major uncertainty in this choice is the ductile-brittle transition temperature (DBTT) under irradiation at operating temperatures. Three-dimensional TBR (100% coverage) for the  $\text{Li}_2\text{O}/\text{H}_2\text{O}$  concept is  $<1.05$ , considered unacceptable for this study. The addition of 6 cm of Be results in  $\text{TBR} > 1.20$  (considered attractive) for the  $\text{Li}_2\text{O}/\text{H}_2\text{O}/\text{Be}$  and  $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Be}$  concepts.

The  $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Pb}$  concept was investigated to determine the viability of a lead neutron multiplier with solid breeders. The preliminary reference design (tokamak version), shown schematically in Figure 1(b), consists of PCA stainless steel pods filled with liquid lead which surrounds coolant tubes and breeder tubes.

Key issues for the concept are coolant tube reliability, liquid metal embrittlement (LME), corrosion, and operating difficulties. Tube reliability can be improved through the use of DWT. The use of HT-9 instead of PCA would increase

maximum allowable temperature based on corrosion limits; however, LME is a concern for both materials. Operational difficulties appear to be generic to the combination of lead (327<sup>0</sup>C melting point) and water coolant. Lead freeze-up, which could break breeder and coolant tubes, must be prevented by the operator during shutdown periods. Higher coolant temperatures would alleviate the problem somewhat, but would sharply increase coolant operating pressure.

Pressurized water has been considered as a separate coolant for LiPb. The viability of the concept has not yet been established. First-order investigations of tritium permeation into the coolant, the most important concern for the concept, are being conducted. The low solubility of tritium in the LiPb breeder leads to relatively high tritium partial pressures in the blanket. As a result, permeation rates through single-wall coolant tubes are high. Multiple-wall tube assemblies are being investigated. Their feasibility will depend on tritium oxidation rates within the actively purged annuli and the effectiveness of oxides as tritium barriers.

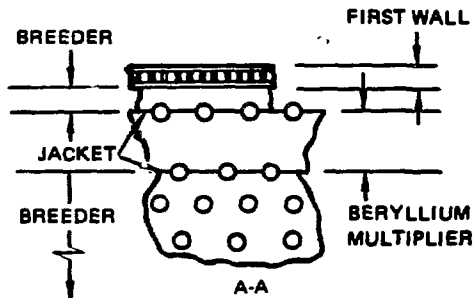
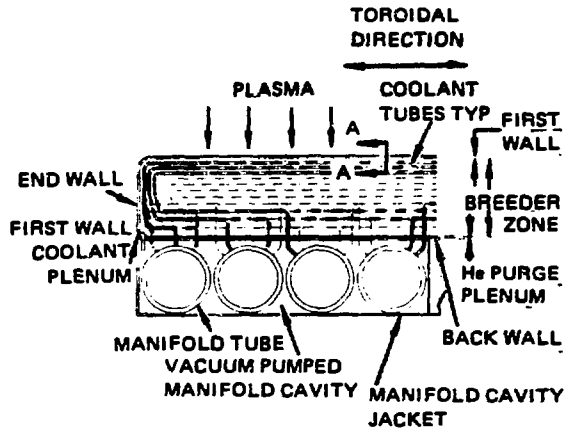
The  $\text{Li}_2\text{O}/\text{H}_2\text{O}/\text{Be}$  and  $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Be}$  concepts compare favorably overall to other concepts being evaluated, and are being developed further for tokamaks and tandem mirrors. The  $\text{LiAlO}_2/\text{H}_2\text{O}/\text{Pb}$  concept appears less attractive, and will not be studied further. For the  $\text{LiPb}/\text{H}_2\text{O}$  concept, concerns regarding tritium permeation into the coolant must be resolved before it can be pursued further. The paper will discuss the reference designs and results of key issue investigations for all water-cooled concepts studied.

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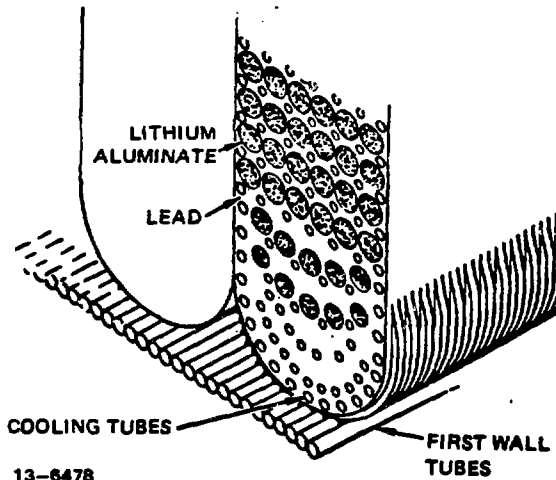
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(Be NEUTRON MULTIPLIER OPTION)

(a) WATER COOLED SOLID BREEDER BLANKETS WITH AND WITHOUT Be NEUTRON MULTIPLIER



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(b)  $\gamma$ -LiAlO<sub>2</sub> BLANKET WITH LEAD NEUTRON MULTIPLIER

FIGURE 1 WATER-COOLED SOLID BREEDER BLANKET DESIGNS

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