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A PRECONCEPTUAL ACCELERATOR-BREEDER DESIGN FOR FISSILE MATERIAL AND ENERGY PRODUCTION*

Peter S. K. Lam**

Abstract

A preconceptual accelerator-breeder design has been developed with improved capability to produce fissile material and thermal power. These improvements allow the design to have the dual role of fissile material and electricity production.

I. Introduction

In a previous study,[1] a sodium-cooled accelerator-breeder plant using a 300 mA, 1-GeV proton beam and a stagger stainless-steel target was developed. The breeding potential of a wide range of UO_2 and ThO_2 blankets was evaluated. Auxiliary studies of the principal factors governing fissile material productivity and overall energy balance, key plant design features, safety issues, fuel cycle options and cost analyses were conducted. There, emphasis was placed upon demonstrating preliminary feasibility and furthermore, conducting parametric studies. One of the many key areas identified in the study for further development was that, although the stagger stainless-steel target appeared to be a feasible design in terms of acceptable power density distribution and heat removal, the overall fissile material production rate was low (approximately 1.5 kg plutonium per day). To that end, an improved target/blanket design has been developed and the results reported here.

II. Preconceptual Design Description

Primarily because of its higher mass number and therefore higher yield of spallation and evaporation neutrons, tungsten was selected to replace stainless steel as the target material in the stagger solid rods target arrangement. Furthermore, a two-region radial uranium blanket with 0.200 and 0.522 fuel volume fractions was used to surround the target. These fuel volume fractions were based on results of a parametric study in which various combinations of fuel volume fractions in a two-region blanket were investigated with respect to radial power profile and fissile material production rate. An inner radial blanket with a lower fuel volume fraction permits more spallation and evaporation neutrons to enter the outer radial blanket, thereby resulting in an improved radial power profile. Figure 1 shows the new target/blanket configuration.

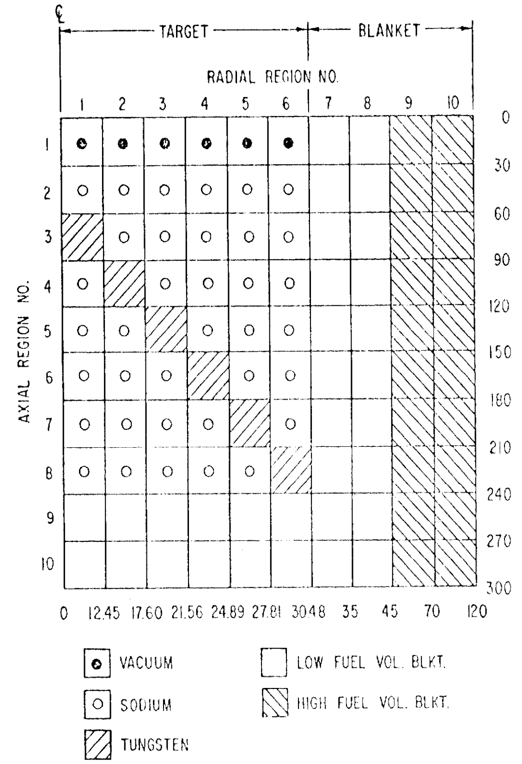

Fig. 1. Target/Blanket Region Subdivisions.

III. Transport Calculations

Particle transport and energy deposition calculations were performed by coupling a high-energy transport code HETC[2] with the low-energy neutron transport program VIM.[3] The HETC code was developed at Oak Ridge National Laboratory specifically for high-energy particle transport computation, and the Monte-Carlo program VIM was developed at Argonne National Laboratory for calculation of neutron interactions on a continuous energy cross section basis.

IV. Fissile Material and Electricity Production

For the target/blanket configuration shown in Fig. 1, an approximately 46% improvement in fissile material production and thermal energy output relative to the previous design[1] was observed: 2.2 kg Pu/day and 930 MWt for the new design vs. 1.5 kg Pu/day and 636 MWt for the previous design. The increased fissile productivity reduces the cost per unit mass of fissile material produced, thus enhances the role of the design as a fissile material producer. Furthermore, the increased thermal output lowers the operating cost of electricity generation, as illustrated in Fig. 2 in which the annual operating cost of three different waste heat options (direct heat rejection, process heat utilization and electricity production) was shown as a function of thermal power output. This range of fissile productivity and thermal energy output allows, based on economics considerations, the preconceptual design to have the dual role of producing fissile material and electricity.

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**Argonne National Laboratory, Applied Physics Division, 9700 South Cass Avenue, Argonne, Illinois 60439.

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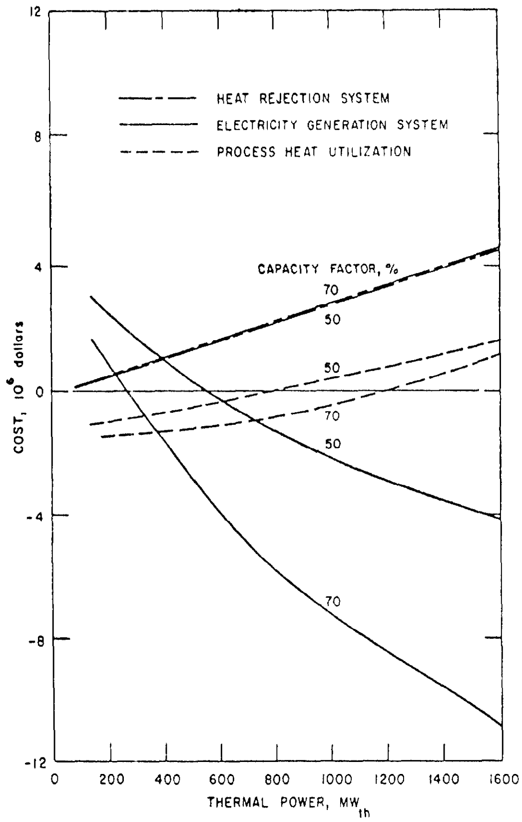

Fig. 2. Annual Cost vs. Thermal Power Output for Heat Rejection, Electricity Generation and Process Heat Utilization.

V. Conclusions

In the long run, in the absence of rapid fast breeder deployment, the accelerator-breeder generally appears to be a viable energy option as a supplier of fissile material to burner/converter reactors or as a supplier of electrical energy. In particular, the proposed accelerator-breeder preconceptual design can have the dual role of producing both fissile material and electricity.

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