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New proposal for the fast energy amplifier

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Abstract

The conceptual design of Rubbia et al. CERN/AT/95-44 (ET), 1995, for an accelerator driven system, known as the Energy Amplifier (EA), proposes use of a spallation neutron source that is in turn induced by protons from a Cyclotron or a Linac, in a subcritical array that makes use of liquid lead coolant. This paper introduces some qualitative changes to the concept of Rubbia et al. examining use of more than one point of spallation, in order to reduce the requirements placed on proton energy and current of the accelerator, and specifically to obtain a flatter power density distribution.

Keywords: Hybrid systems; Spallation process; Helium coolant

1. Introduction

A coupled system consisting of a spallation source and a subcritical array of fuel (i.e. an Accelerator Driven System, ADS) may have a positive gain of energy (net energy/energy to operate the accelerator). This fact has motivated innovative concepts of accelerator driven reactors in which Thorium has been considered as the fuel (Rubbia et al., 1995). The proposal is for a fast Energy Amplifier (EA) using a modular three stage modular cyclotron of 1 GeV, 12.5 mA to induce spallation with protons. The fuel, designed as an hexagonal array of pins immersed in liquid lead that circulates in natural convection, forms the subcritical core surrounding the spallation source. In the present work, the design of the subcritical core is for a solid lead calandria with the fuel elements in channels cooled by Helium. This would allow on-line refueling or shuffling, and utilization of a direct thermodynamic cycle (Brayton), the latter being more efficient than a vapor cycle. Although calculations to demonstrate the feasibility of the present design are as yet still underway, the ideas do not violate the basic physical principles of the EA.

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2. The design

The main modification to the design considered by Rubbia et al. (1995) is the introduction of more than one point of spallation. This is done in order to make the neutron distribution more uniform and to reduce requirements placed on the performance of the accelerator. Also, instead of liquid lead as coolant, in the present concept, use is made of He gas. The He coolant circulates in channels of a cylindrical calandria of solid lead which contain bundles of fuel elements, being of a design utilized in the Canadian Reactor (CANDU). Helium coolant has been used successfully in the *high temperature reactor*, and has been proposed for use in fast systems like the *gas cooled fast breeder reactor*. This situation can be compared with that for the liquid lead design, for which there has been little technological experience. Furthermore, He as coolant allows use of the direct thermodynamic cycle high efficiency (47%) Brayton cycle gas turbine, these being more efficient than the thermodynamic cycle proposed in the EA of Rubbia et al. (1995). Previous calculations gave us a K_{eff} of the order of 0.98. Another modification is that the lead between the fuel elements will be kept solid. As such, it must be guaranteed that the temperature adjacent to fuel elements remains below the melting temperature of lead (328°C). In order to guarantee such a situation, helium pipes are placed between the fuel elements. A uni-dimensional model has been

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employed to analyze heat transference. Using this approach, the temperature next to fuel element has been calculated to fall from 707°C (cladding temperature) to 160°C, this being sufficient to satisfy the design requirements.

References

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