DEFINITION OF BREEDING GAIN FOR MOLTEN SALT REACTORS

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ABSTRACT

The graphite-moderated Molten Salt Reactor (MSR) is a potential breeder reactor using the thorium fuel cycle. The MSR has unique properties due to the possibility of making changes to the salt composition during operation. Most important is the extraction of protactinium, which separates the fissile uranium production into two volumes: the reactor core and the external stockpile. The paper focuses on the definition of breeding gain in such a system. The prospects of using breeding gain expressions defined for solid fuel reactors are investigated and new definitions are given which incorporate the processes occurring in the reactor core and the external stockpile. The difference of the growth rate of the mass of fissile material and breeding gain is pointed out. The new definitions are applied to an optimization study of the graphite-salt lattice of a breeder MSR.

Key Words: molten salt reactor, thorium fuel cycle, breeding gain

1. INTRODUCTION

There is a renewed interest in molten salt reactors (MSR) since the design was chosen by the Generation IV International Forum. The MSR uses fluid fuel which consists of actinide salts and other salts providing a low melting point and good heat transfer properties. The concept of the MSR has advantages on fuel fabrication, neutron economy and high temperature operation. It is also possible to change the composition of the salt during operation by extracting fission products or refueling the reactor on-line. Because of these advantages the MSR is a promising breeder reactor. Our study considers a moderated MSR which is a possible breeder on the thorium fuel cycle.

The research of an MSR running on the thorium cycle was started in the 1960s at the Oak Ridge National Laboratory. The goal of the project was to develop a graphite-moderated breeder reactor (MSBR) [1]. That research proved the feasibility of such a reactor after which the project was cancelled due to fierce opposition with the sodium cooled fast reactor. Recently, the concept was re-assessed in the frame of the MOST project [2]. An extensive study is carried out in France at Laboratoire de Physique Subatomique et de Cosmologie (LPSC), where first a design of a moderated reactor was developed on the basis of the MSBR [3], currently the project focuses on a fast breeder reactor [4].

The thorium fuel cycle works similar to the uranium one. The fertile isotope is $^{232}$Th which forms $^{233}$U after a neutron capture and 2 beta decays. The in-between steps are $^{233}$Th and $^{233}$Pa. The important difference between the two cycles is the half-life of the isotopes. $^{233}$Pa has a half-life of 27 days, which gives a high chance to capture a neutron before it decays leading to $^{234}$U, a non-fissile isotope. To avoid this, it is possible in a MSR to extract part of the protactinium from the salt during operation and to store