MULTI-RECYCLING OF ACTINIDES IN THORIUM BASED FUELS

Jan Leen Kloosterman
Delft University of Technology
Interfaculty Reactor Institute (IRI)
Mekelweg 15
NL-2629 JB Delft, Netherlands
E-mail: J.L.Kloosterman@iri.tudelft.nl

Harm Gruppelaar
NRG
P.O. Box 25
NL-1755 ZG Petten, Netherlands
E-mail: Gruppelaar@nrg-nl.com

ABSTRACT

Burnup calculations have been performed to assess reactor physics and waste toxicity characteristics of a PWR fuelled with either low enriched UO₂ (LEU) fuel, medium enriched UO₂ (MEU) fuel mixed in ThO₂, or highly enriched UO₂ (HEU) fuel mixed in ThO₂. For all fuels the reactivity coefficients have been calculated as a function of burnup, and the radiotoxicity curves of the spent fuels and loss fractions as a function of storage time. Without recycling, the fuel temperature coefficient of the MEU fuel is strongest negative due to the large quantities of both ²³⁵U and ²³³Th in the fuel. For the HEU fuel, the moderator temperature coefficient is very small negative or even positive, which means that special measures have to be taken. Up to 20,000 years of storage, the radiotoxicity of HEU spent fuel is lowest and that of LEU spent fuel largest. After this period the reverse is true.

After two times recycling of Pa+U in MEU fuel, the radiotoxicity of the reprocessing losses is a factor of 2 less than the radiotoxicity of the LEU spent fuel. If in addition Pu is recycled in MEU fuel, the reduction factor equals a factor of 5 to 10. In this case, the reprocessing factor is significantly larger than that obtained with recycling of Pu in standard (U,Pu) MOX fuel. In general, multi-recycling worsens the reactivity coefficients with several tens of percents.

I. INTRODUCTION

The use of ThO₂ as a carrier material for the fuel in a PWR instead of UO₂ offers the possibility to reduce the production of plutonium and minor actinides per unit electricity generated. In standard UO₂ fuel, plutonium and minor actinides are produced during burnup due to neutron capture reactions by ²³⁵U. When ThO₂ is used as a matrix, much less plutonium is produced due to the lower atomic number of thorium. Of course, more protactinium and uranium are produced in this case among which the hazardous isotopes ²³³U and ²³⁴U. This raised the question whether the use of ThO₂ is an effective way to reduce the radiotoxicity of spent fuel. This paper aims at investigating the reactor physics aspects of using ThO₂ as a matrix in PWR fuel, and the possibilities to reduce the radiotoxicity per unit electricity generated.

The reference PWR design is a French N4 reactor [1] loaded with 4% enriched UO₂ fuel in a five batch mode. The achievable burnup is 47.5 GWd/tHM. Because ThO₂ is able to withstand higher burnup values and because the general trend in PWR fuel management is to increase the fuel burnup, a target burnup value of 60 GWd/tHM has been chosen for the fuels investigated here. The corresponding ²³³U enrichment of the standard UO₂ fuel is 4.45%.

The fuel temperature coefficient (FTC), the moderator temperature coefficient (MTC), the boron reactivity worth (BRW) and the moderator void coefficient (MVC) have been calculated as function of burnup for the following fuels:

- LEU Standard UO₂ fuel (4.45%).
- MEU Medium enriched UO₂ fuel (20%) mixed in ThO₂.
- HEU Highly enriched UO₂ fuel (93%) mixed in ThO₂.

The radiotoxicity of the spent fuel has been determined for the once-through case and for recycling of Pa+U in MEU fuel, for recycling of Pa+U+Pu in MEU fuel and for recycling of Pa+U in HEU fuel.