Section 3. Reactor physics studies

Reactor physics aspects of plutonium burning in inert matrix fuels

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Abstract

Burnup calculations have been performed on fuels containing either reactor grade or weapons grade plutonium mixed in an inert matrix or mixed in a thorium oxide matrix. At each branching during burnup, the fuel temperature coefficient, the moderator void coefficient and the boron reactivity worth have been calculated. From the reactor physics point of view, use of thorium oxide as a matrix compares best with irradiation of plutonium in ‘ordinary’ (U, Pu) mixed oxide fuel. Because the thermal properties and the irradiation resistance of thorium oxide are generally better than of uranium oxide, the irradiation of plutonium (either reactor or weapons grade) in a thorium oxide matrix seems without problem. The use of an inert matrix to irradiate plutonium reduces the fuel temperature coefficient by a factor of two to three, which is beneficial from the viewpoint of the power reactivity defect, but disadvantageous from the viewpoint of reactivity induced accidents. Furthermore, the absence of 238U or 232Th in the matrix deteriorates the moderator void coefficient. Whether inert matrix fuels are feasible or not depends to a large extend on the possibilities to increase the magnitude of the moderator void coefficient and on the thermal properties of the matrix, like heat conductivity and melting point. © 1999 Elsevier Science B.V. All rights reserved.

1. Introduction

Burning of plutonium is most effectively done in a matrix with no uranium present, which can be accomplished in so-called inert matrices or in thorium oxide. Several matrices have been proposed and the characterisation of these is subject of worldwide research [1–3]. Besides the materials behaviour of inert matrices, the reactor physics behaviour of uranium-free fuels is also investigated, as this may be quite different from ‘conventional’ uranium oxide fuels [4–6]. For example, the absence of uranium in the fuel significantly influences the burnup reactivity swing, the reactivity coefficients and the kinetic parameters of the fuel.

In this paper the fuel temperature coefficient (FTC), the moderator void coefficient (MVC) and the boron reactivity worth (BRW) have been calculated as a function of burnup for plutonium oxide mixed in an inert matrix and for plutonium oxide mixed in thorium oxide. Two different plutonium compositions have been used: reactor grade (RG) plutonium and weapons grade (WG). The fuel compositions are those described in the international benchmark on non-fertile fuels organised by PSI [5].

2. Benchmark description

The geometry consists of a PWR fuel pin with a moderator to fuel ratio of 1.9, similar to that of present day reactors. Four different matrix compositions have been used, as shown in Table 1.

As mentioned, two different plutonium compositions have been used: RG and WG. The isotopic compositions are given in Table 2.

The plutonium density in the fuel is the same for either RG or WG plutonium, but differs for each matrix to compensate for the extra neutron absorption by the matrix. Table 1 gives the plutonium density for each of the six different matrix/fuel compositions calculated.