MIXED OXIDE FUELS WITH MINOR ACTINIDES FOR THE FAST REACTOR

PROBLEM WITH TI-208 WHEN BURNING NP-237 IN A FAST REACTOR

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presented by Dr. L. BAESTLE

'Mixed* Oxide *Fuels with Minor Actinides for the Fast Reactor'

Excerpts from a paper of same title by S. PILATE, R. de WOUTERS, G. EVRARD (BELGONUCLEAIRE), H.W. WIESE (KfK, Karlsruhe) and U. WEHMANN (INTERATOM), presented at the ENS/ANS Conference on the Physics of Reactors : Operation, Design and Computation (PHYSOR), Marseille, April 1990.

<u>Abstract</u>

The addition of a few percents of Neptunium-237 to the fuel of a large fast breeder like EFR is found advantageous to the core operation, as it allows to reduce the plutonium enrichment, to lower the burnup reactivity loss (and simplify the design of control rod absorbers) and to increase the plutonium breeding gain. The two latter effects are also found in the case of plutonium ageing (long storage) leading to the accumulation of Am-241. If required, the use of uranium from reprocessing does not bring noticeable penalties on reactor operation. The efficiency of the FBR as an actinide burner is compared to that of U- and MOX-LWRs and found equal or better, depending on the isotope.

<u>Introduction</u>

Earlier similar work was already published for the case of Neptunium-237, added to the fuel of the SUPERPHENIX and SNR2 cores. In SNR2, the fuel was assumed to stay in pile 1370 equivalent full power days (EFPD), i.e. 5 years at a 0.75 load factor, reaching a peak burnup target of about 16 % (heavy atoms).

The case of the European Fast Reactor (EFR) is considered here, with a target peak burnup of 20 %, corresponding to 1650 EFP days over a period of 6 years.

Simple burnup calculations were performed starting with an average fuel enrichment of 20.9 % and a reference plutonium isotopic composition of about 1/58/24/9/5 % (Pu-238/239/240/241/242) plus 3 % of Am-241, a simplified and averaged core composition of the current EFR design.

in parallel, the ORIGEN-2 and KORIGEN code versions were used, so as to test the sensitivity of the results to the methods and data. This sensitivity was found to be small enough to guarantee the trends presented below.

Effect of ND-237 on FBR Core Properties

The main calculation was made with an amount of 2.3 % Np, chosen to limit the end-of-life relative content of Pu-238 to 5 % of the total discharged Pu. This ratio is considered prudent not to exceed, because it heats up the fuel, affecting fabrication and reprocessing. It is worthwile to notice that in the case of multiple recycle of plutonium in LWR reactors, one could also approach 5 % Pu-238/Pu, so that the problems would be similar.

The insertion of 2.3 % Np on the main core properties leads to three advantages :

- the plutonium enrichment is reduced from 20.9 to 20.0 %,
- the burnup reactivity loss is reduced by 22 % relative,
- the plutonium breeding gain increases by + 0.06, a substantial gain explained both by the lowered enrichment and the better fuel balance.

Effect of Am-241 on FBR Core Properties

The MOX fuel can contain much Am-241, either if Americium is not separated from plutonium at reprocessing, or if plutonium fuel has to be stored several years before reactor loading. The consequences of plutonium ageing on fast reactor performances have been assessed by comparing the loading of the reference fuel with the loading of the fuel after 6-year storage, so that the Pu-241 and Am-241 relative amounts become, respectively, 7 and 5 %.

The results show that this Americium build-up has no adverse effect on reactor operation : while the reactivity of fresh fuel has decreased, that of the fully burnt fuel also decreases, but less markedly. To compensate this, a slight fuel overenrichment is needed (21.2 % instead of 20.9). The reactivity requirements of the control rod systems are smaller, and the plutonium breeding is improved by + 0.03.

The last beneficial effect is due to the conversion of part of the Am-241 into Cm-242, which itself decays into Pu-238 : there is a ‘return’ to the beginning of the Pu chain, so that we are in the same favorable situation as above for Np-237. The consequence of the improved breeding gain is a mitigation of the penalty in terms of additional loaded Pu mass due to the ageing period.

Calculations with Various Pu Compositions

The calculations with Np-237 and Am-241 have been repeated with two different plutonium compositions : Variant ‘a’ is a clean plutonium vector separated from MAGNOX spent fuel, and Variant ‘b’ is a degraded vector supposedly discharged from a MOX-fuelled PWR at 45 GWd/t. As far as Np-237 insertion is concerned, all advantages quoted above are confirmed for both variants : decrease in plutonium enrichment and in burnup reactivity loss, and increase in plutonium breeding gain. With Variant ‘b’ the end-of-life Pu-238 concentration is larger (but the increase is not linearly correlated with the initial amount).

Comparison of Minor Actinide (MA) Transmutation in Various Reactors

Three types of power reactors are compared with respect to the aim of reducing assumed stocks of separated Np-237 and Am-241 :

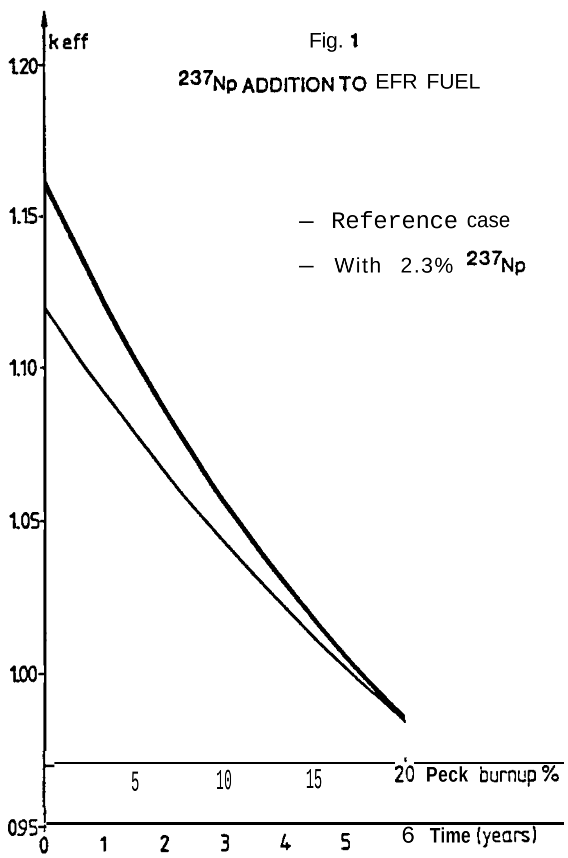
a) Fast breeders of a design similar to the current EFR project,
b) PWR fuelled with enriched uranium, with a discharge burnup 45 GWd/t,
c) PWR fuelled with self-generated Pu-enriched MOX and the same residence time.

The transmutations occurring in samples of Np-237 and Am-241 were estimated with the programme ORIGEN-2 and KORIGEN.

The general conclusion is that both the U-fuelled LWR and the FBR can burn between 17 % and 27 % of an initial quantity of Np-237 or Am-241 during a standard assembly residence time. Real advantages of the FBR are essentially related to the high reactivity worth of the transmutation products, which improve the breeding gain and do not request additional overenrichment.

Neptunium or Americium recycling in MOX-fuelled LWR seems comparatively unattractive from the transmutation efficiency viewpoint.

6 viewfoils are attached, to illustrate this short text (referred to as Fig. 1, 2, 3, Tables 1, III, IV).


k eff
Fig. 1
237Np ADDITION TO EFR FUEL
— Reference case
— With 2.3% 237Np
1.20
1.15
1.10
1.05
1.00
0.95
5 10 15 20 Peck burnup %
0 1 2 3 4 5 6 Time (years)

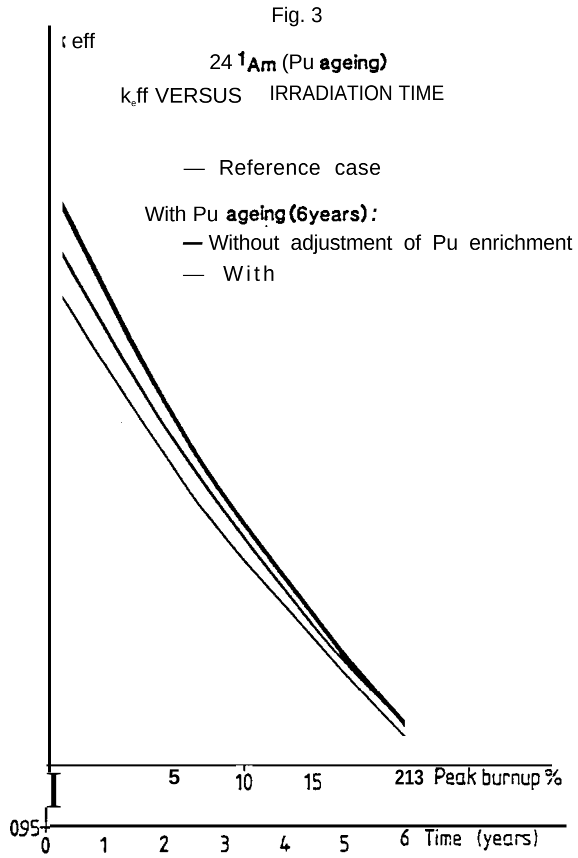


Fig. 3
k eff
241Am (Pu ageing)
keff VERSUS IRRADIATION TIME
— Reference case
With Pu ageing (6years):
— Without adjustment of Pu enrichment
— With
5 10 15 213 Peak burnup %
0.95
0 1 2 3 4 5 6 Time (years)

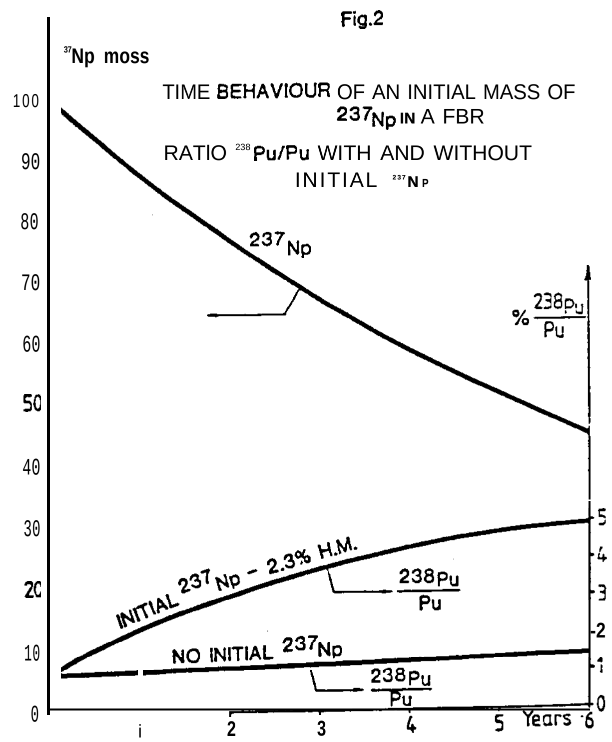


Fig.2
237Np moss
TIME BEHAVIOUR OF AN INITIAL MASS OF 237Np IN A FBR
RATIO 238Pu/Pu WITH AND WITHOUT INITIAL 237Np
100
90
80
70
60
50
40
30
20
10
0
237Np
% 238Pu/Pu
INITIAL 237Np - 2.3% H.M.
238Pu/Pu
NO INITIAL 237Np
238Pu/Pu
5 4 3 2 1 0
1 2 3 4 5 Years 6

TABLE I

Effect of Np-237 Insertion, Am-241 (Pu Ageing) and Reprocessed Uranium on FBR Core Properties with a Typical Pu Vector of the Loaded Fuel

Cases	Enrichment a/c (Pu + Am)/HM	Burnup Reactivity Loss (Relative to Reference)	Plutonium Breeding Gain Change from Reference	Discharged Pu-238/Pu (%)
1. Ref.	20.9	1.		1.1
2. 2.3 Z Np-237/HM	20.0	0.78	0.06	5.2
3. Am-241 (Pu ageing)	21.2	0.93	0.03	1.4
4. Reprocessed U	20.7	1.03	0.01	1.2

TABLE III

End-of-Life Quantities of MA Issued from an Initial Unit Mass of Np-237

Isotope	FBR (a)	$LWR-UO_2$ (b)	LWR-MOX (b)
Np-237	0.440	0.367	0.461
Pu-238	0.282	0.345	0.377
Pu-239	0.041	0.069	0.059
Cm-242	3.4 E-7	1.2 E-4	1.8 E-5
Cm-244	2.5 E-8	2.7 E-4	1.2 E-5
Fissioned	0.225	0.165	0.075

TABLE IV

End-of-Life Quantities of MA Issued from an Initial Unit Mass of Am-241

Isotope	FBR (a)	$LWR-UO_2$ (b)	LWR-MOX (b)
Am-241	0.412	0.034	0.126
Pu-238	0.197	0.355	0.388
PU-239	0.026	0.064	0.061
Pu-240	2.1 E-3	0.020	0.017
Cm-242	3.4 E-2	4.3 E-2	7.3 E-2
Cm-244	1.8 E-3	4.1 E-2	2.4 E-2
Fissioned	0.214	0.271	0.156

(a) Irradiation during 1650 EFPD
(b) Irradiation during 1100 EFPD

'Problem with Tl-208 when burning Np-237 in a Fast Reactor'

Summary in English of a thesis published in French by J. LOBRY (Faculté Polytechnique de Mons)

Potential penalties on fuel cycle operations such as transport, storage, reprocessing and fabrication of fuel containing reprocessed plutonium can arise due to the buildup of the hard gamma ray emitter Tl-208, a daughter product of (n, 2n) reactions on Np-237. Parametric studies, with the ORIGEN-2 depletion programme, have been carried out with various storage times before and after reprocessing of fast breeder fuel containing respectively 0 % and '2.3 % Np-237. The effect of Np-237 on the gamma dose, with special attention to the Tl-208 component, has been investigated in the fuel before reprocessing, and in the reprocessed uranium and plutonium effluents. The addition of Np-237 does not affect significantly the gamma dose in the irradiated fuel before reprocessing, which is predominantly due to fission products. After reprocessing, the gamma dose in the uranium flow is multiplied by a factor 30, due to the Tl-208 generated from the Np-237. A factor of about 2 is calculated in the plutonium flow. Reduction of the gamma dose would entail long-storing times of the plutonium, which conflict with the incentive to limit the amount of AM-241, itself a precursor of Np-237, so that a compromise is to be found.