Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Forschungszentrum Karlsruhe GmbH, Institut für Reaktorsicherheit
Postfach 36 40, 76021 Karlsruhe
B. Merk, C.H.M. Broeders

On the Accumulated Plutonium Mass against the Background of the Fixed Electricity Amount Regulated by Law in Germany

I INTRODUCTION

In the actual situation in Germany the net amount of electricity (roughly 220 TWd) to be produced is fixed by law. The over all thermal energy produced can be calculated to 666 TWd gross in about 33 years [1,2]. Besides this worth a postulated lifetime extension up to 900 TWd thermal in a 10 year period will be studied.

II CYCLE STUDY

II.A Used Calculation Methods

The calculations are preformed with the standard software KAPROS. A special procedure (KARBUS) using 69 group cell calculation for best estimate weighting function determination for one group collapsing for burnup calculations is applied. The scenario design is performed in EXCEL (see Fig. 1).

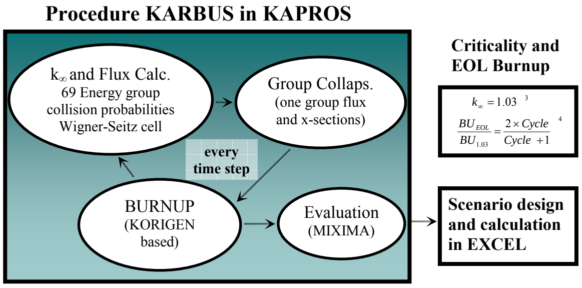

Fig. 1: Schematic diagram of the calculation process

II.B The Scenarios

The Pu production will be investigated for 4 different scenarios. The once-through scenario (direct disposal) is the upper limit for the Pu production. Idealized single and double Pu recycling scenarios provide the lower limits. Additionally a close to reality scenario which represents the situation in Germany is presented. This situation is characterized by an average MOX use of about 15% in the core and a limited reprocessing of roughly 40% of the used UOX fuel.

The scenarios are characterized by the following boundary conditions:

- Once-through (OT) – time averaged burnup of 41 GWd/tHM in 949 days in 3 cycles.
- Single Pu recycling (MOX1) – identical burnup structure, reuse after 5 years (3+2).
- Double Pu recycling (MOX2) – identical burnup structure, use of natural uranium in the MOX fuel and reuse after 12 years (10+2).
- Close to reality Pu recycling (rMOX) – identical Burnup structure, reuse after 13 years (8+5), MOX use starting after roughly 13 years.

The time dependent behaviour of k_∞ versus burnup for the different used fuel materials is shown in Fig. 2. To collocate the different fuels in one core all curves for k_∞ versus burnup have to meet at k_∞ =1.03 at the identical burnup.

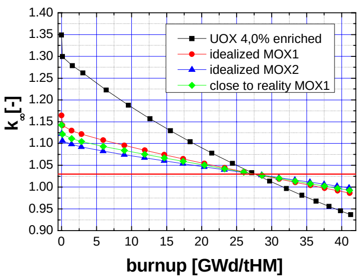

Fig. 2: Burnup dependent k_∞ evolution for the different fuel materials

II.C Lifetime by Law

The time dependent accumulated Plutonium mass for the different scenarios is shown in Fig. 3. In the OT scenario the Pu mass is rising linearly due to the used approximation, time averaged burnup. After the regular lifetime there are about 160 tons of Pu accumulated. This amount is reduced by 25% for the MOX1 scenario, by roughly 35 % for the MOX2 scenario and by about 15% in the foreseen scenario in the German reactor park.

II.D Lifetime Extension

The energy production is increased by roughly 35% (from 666 TWd to 900 TWd) in the case of a life time extension of 10 years and average burnup is increased to 49 GWd/tHM. The accumulated Pu masses after this time period are changed in the following way. Additional 22% for OT, +20% for MOX1, +13% for MOX2 and about 27% more for a German scenario without re-entry in reprocessing.
The minor actinide production is over proportional. There will be about 45% more Am for all scenarios and about 50% more Cm.

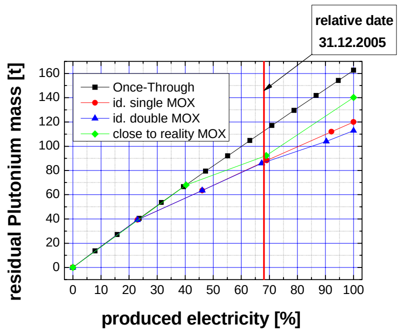

Fig. 3: Residual Pu mass for the different scenarios

II.E Plutonium Reduction and Quality

The relative Pu mass for the production of 1 ton of MOX2 fuel is indicated in Fig. 4. About 170 kg of Pu produced in the OT scenario is reduced to about 100 kg at the end of the MOX2 scenario. In this time the content of Pu-239 is reduced by about 60%. Thereby the proliferation risk is reduced significantly.

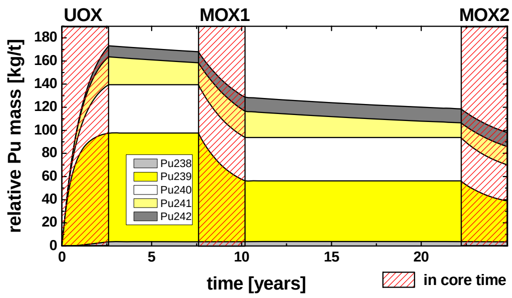

Fig. 4: Relative Plutonium mass needed fort he production of 1 ton of MOX 2 fuel

III CONCLUSIONS

The estimation of the accumulated Pu mass for a scenario close to the reality in Germany shows the benefit of reprocessing and MOX fuel use. A significant reduction of the Pu amount by 20 tons is achieved during the time period of MOX use. A part of the possible achievement is lost due to the termination of reprocessing by law in 2005.

The lifetime extension leads for all scenarios to an under proportional amount of Pu produced compared to the additionally produced amount of energy.

The Plutonium mass is reduced by roughly 40% in the double recycling scenario and the Plutonium composition is changed in a way that reduces the proliferation risk significantly.

	Once-Through (OT)	Single MOX (MOX1)	Double MOX (MOX2)	Close to reality MOX (Creal)
Lifetime by Law (LL) tons compared to OT	~160 100%	~120 -25%	~110 -35%	~140 -15%
Lifetime Extension tons compared to LL	~36 +22%	~24 +20%	~15 +13%	~38 +27%
Over all after 42 years tons compared to Creal LL	~196 140%	~144 103%	~125 90%	~178 127%

Tab. 1: Overview on the results for the different scenarios

IV REFERENCES

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4. Broeders: "Investigations Related to the Burnup of Transurania in Pressurized Water Reactors", FZKA 5784 Version March (1999)