"System Studies on the Advanced Fuel recycle at PNC"

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1.Introduction

In June 1994, the Atomic Energy Commission (AEC) of Japan formulated a "Long-Term Program for Research, Development and Utilization of Nuclear Energy". It entails that a development of advanced nuclear fuel recycling technology should be developed in the long range, on the basis of fast breeder reactor technology. In accordance with this new policy, PNC is starting development of advanced fuel recycle system. The advanced fuel recycle system is featured by the recycling of Minor Actinides (MA:Np,Am,Cm) in the fuel cycle.

This new approach to the future fuel-cycle stands on the following principal objectives ; (1) Reduction of the burden to the environment ; as the result of improvements both in cumulative production and distribution to the wastes of MA and Plutonium, by their high recovery and burning in the fast reactor core, (2) Improvement of nuclear fuel cycle economy ; by drastic modification and simplification of fuel cycle system in the FBR commercialization stage, (3) Enhanced proliferation resistance ; by adapting the co-processing of the plutonium with other actinides. (see Fig.1)

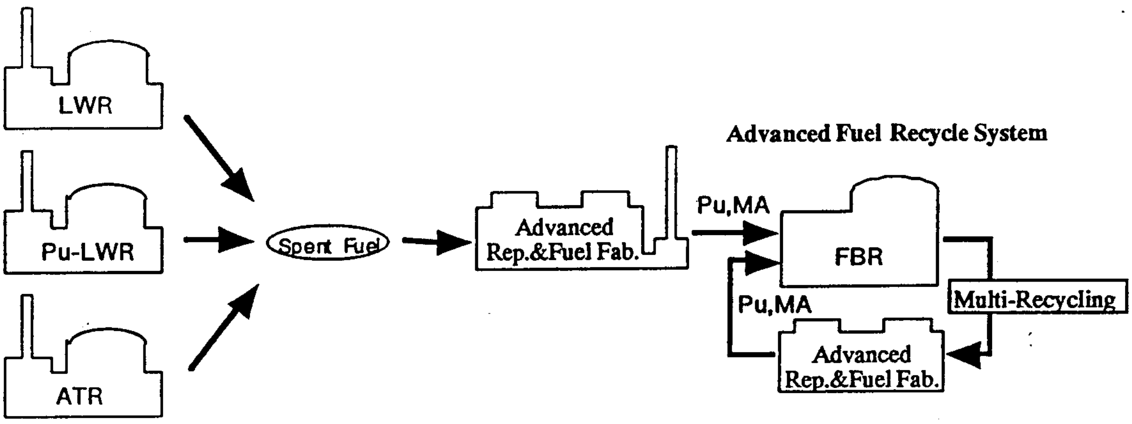

Fig.1 Concept of the actinide recycle system

2. Purpose of the Advanced Fuel Recycling

① Reducing burden to the global environment

Because MA and the residual plutonium dominate the toxicity of High Level Waste (HLW) for a long period, actinide recycle ensuring its high recovery of MA and Pu , can reduce long lasting toxicity in the HLW. The recovered MA is recycled and burnt in the FBR, thereby the total MA inventory in the fuel cycle does not simply increase but is maintained constant at a low level.

Through these features of actinide recycle, it is expected to make the waste disposal and the fuel cycle be more understandable and acceptable to the public.

② Improvement of nuclear fuel cycle economy

The nuclear power generation cost of fast reactor cycle mainly depends on the capital cost of the reactor, moreover, the influence of MA loading to the FBR core is negligibly small to the core performance and efficiency . Thereby, MA recycling to the core does not affect the generation cost so much.

Though the backend cost for fuel reprocessing and fabrication is possibly affected by the treatment of MA, if new design criteria of the cycles are applied which encourage the simplification of the process(e.g. imperfect purification of plutonium, rationalized waste handling etc.), it is possible to reach a reasonable and more efficient back-end costs in the FBR commercialization stage.

③ Enhancing proliferation resistance

It has been proposed that the closed fuel cycle with low decontamination has an proliferation resistance. The advanced fuel recycling system has the same feature by the co-recovery of Pu with other actinides or low decontamination of Pu from FPs. In this fuel cycle Pu never exist alone, which provides high barrier against its diversion and theft, and hence provides high reliability to the non-proliferation.

3. Production of Minor Actinides

Minor actinide nuclides are produced in the fission reactor (light water reactor and fast reactor) core by the neutron reaction and its chain. Especially, almost all Am-241 is generated during spent fuel cooling by reaction of the beta decay of Pu-241.

As a result of the operation of a 1000 MWe LWR for a year, production of 24 tons of spent fuel containing 22.6 tons of uranium, 1120 kg FPs, 250 kg Pu, and 20 kg MA is expected.

The production rate of ^{237}Np is large compared with that of Am and Cm in the LWR core using enriched uranium fuel. Almost all ^{237}Np is generated in thermal neutron spectrum by the following reaction.

$$^{235}U(n,\gamma)^{236}U \quad , \quad ^{236}U(n,\gamma)^{237}U \quad , \quad ^{237}U \xrightarrow[6.75d]{\beta^-} {}^{237}Np$$

Am and Cm are produced by the reaction of neutron capture of Pu. Therefore, the production rate of MA in the thermal reactor increases according to the progress of burning.(Fig.2)

On the other hand, a fast neutron spectrum, with generally big fission-to-capture cross section ratio σ_f / σ_c for minor actinide nuclides, can make more efficient use of neutrons for burning of MAs than a thermal spectrum. Therefore, the production rate of MA in the fast reactor decreases according to higher burn up.(Fig.3)

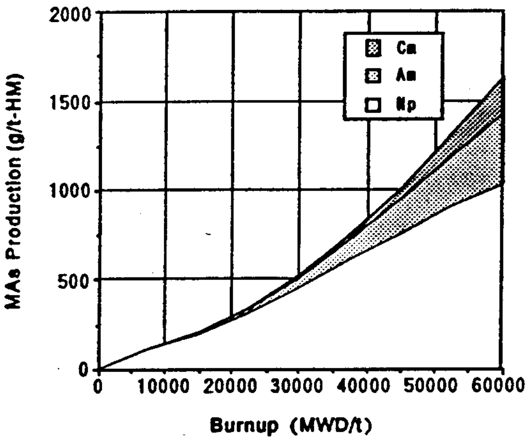

Fig.2 MAs Production in LWR core

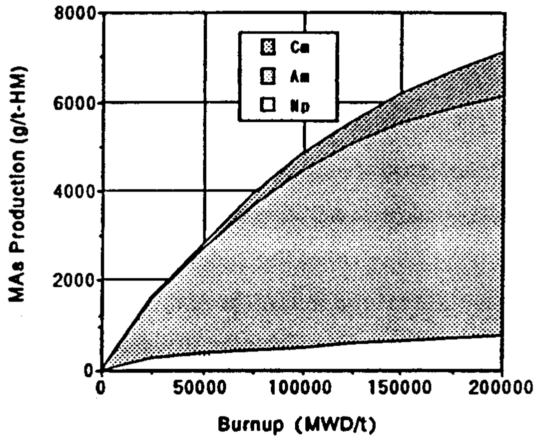

Fig.3 MAs Production in FR core

4. Burning of MA through Fast Reactor

The objective of this section is to analyze Minor Actinide(MA) mass balance, such as the effect of MA accumulation reduction by the advanced fuel recycle and the MA concentration in FBR core fuel, according to the future foreseen nuclear energy production in Japan.

MA mass balance is studied on the assumptions that Plutonium and MA is recovered from the LWR and Pu-thermal reactor and recovered Pu and MA is recycled into fast reactor in multi number of times. Nuclear power generation is assumed to increase to 1000 MWe/y (Fig.4) or 1500MWe/y and introduction of commercial the fast reactor will start in the year 2030. New reactors are assumed to be totally FBR, and LWR reprocessing is assumed to be applied to all spent fuel discharged from LWR and Pu-thermal reactor.

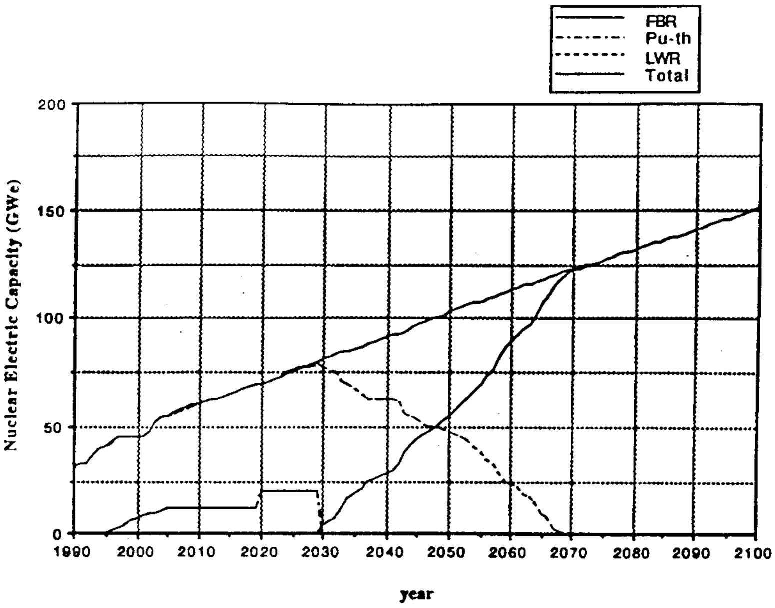

Fig.4 Assumed of Nuclear Electric Capacity

(1) Effect of MA Accumulation reduction

In Case-1(1000 MWe/y), the total MA transferred into the high level waste is calculated to be 310 tons from LWR, Pu-thermal LWR and FBR without recycling of MA. In the case of recycling MA into commercial FBR after the year 2030, the MA existing in the fuel cycle in the year 2100 is reduced to about 60 tons, reducing 80 % of no-recycle value.

The result of this analysis is indicated in Table 1.

And the residual accumulated MA are kept contained in the fuel cycle .(see Fig.5)

In this result, the maximum accumulation of total MA will be indicated about in the year 2065. Reduction ratio of curium is relatively lower than those of americium and neptunium because of the generation of curium by the neutron capture reaction of americium in the FBR core.

Table 1. Effect of MA Transmutation

	Growth of Nuclear Power Generation	
	1000 MWe/y	1500 MWe/y
year 2025-2100 MA Generation (ton)	312 (Np 67, Am 230, Cm 15)	389 (Np 87, Am 283, Cm 19)
MA Accumulation in the year 2100 (ton)	63 (core 40, fuel cycle 22, waste 0.5)	87 (core 56, fuel cycle 30, waste 0.7)
MA Reduction Ratio (%) at the year 2100	80 (Np 88, Am 82, Cm 20)	78 (Np 87, Am 79, Cm 12)

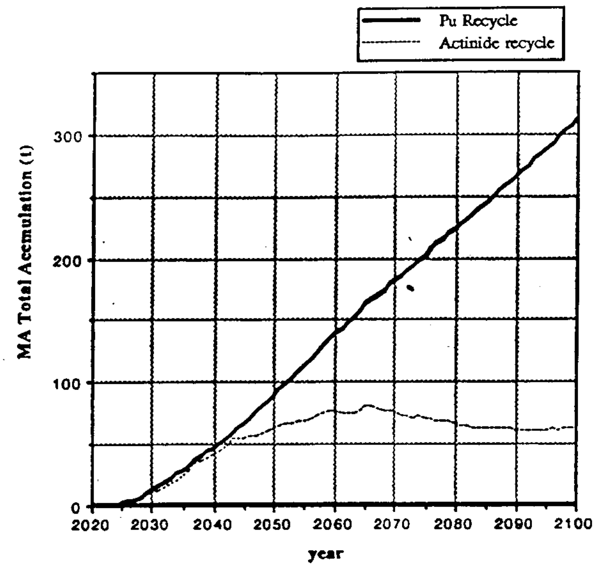

Fig.5 Effect of Minor Actinide Burning in the Advanced Fuel Recycling

(2) MA concentration in FBR fuel

Loading the MA in all-FBRs core homogeneously, MA concentration in FBR fuel is directly influenced by ratio of reprocessed spent fuel among LWR, Pu-thermal and FBR. , Especially, the higher ratio of Pu-thermal spent fuel reprocessing arises this concentration, therefore Pu-thermal spent fuel indicate high content of MA and small ratio of Pu-f.

Due to the MA multi-recycling, the concentration of the loaded FBR fuel and its spent fuel varies in every recycle. MA concentration will decrease gradually by the increasing FBR ratio and the effect of MA burning in FBR. In the year 2100, MA concentration will reach about only 0.7%.(see Fig.6)

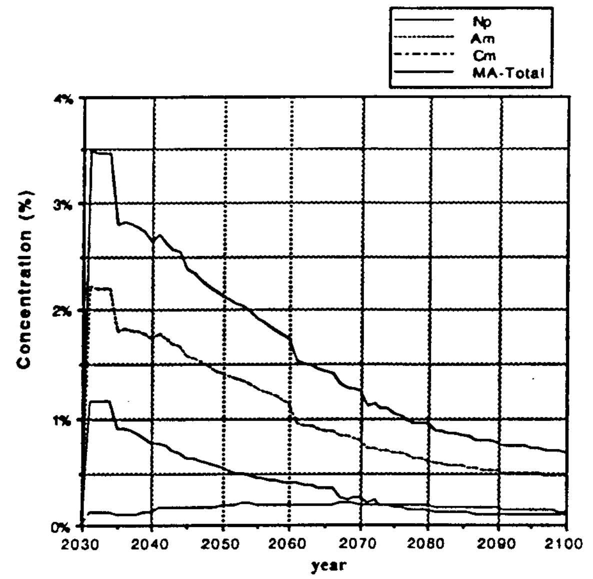

Fig.6 MA Concentration in the FBR Loading Fuel

(3)Effect of potential hazard reduction

MA and the residual plutonium are the dominant toxicity from the high level waste (HLW) for a long time. In the present fuel reprocessing, high level waste is estimated to contain 100% minor actinide and about 0.5% plutonium from spent fuel. In addition, spent cladding hull and MOX secondary wastes contaminated from small quantity of plutonium.

The advanced fuel recycle intends to reduce the long-lived radiotoxicity by recovering MA and reducing Pu losses from not only HLW but also other wastes. (Fig.7)

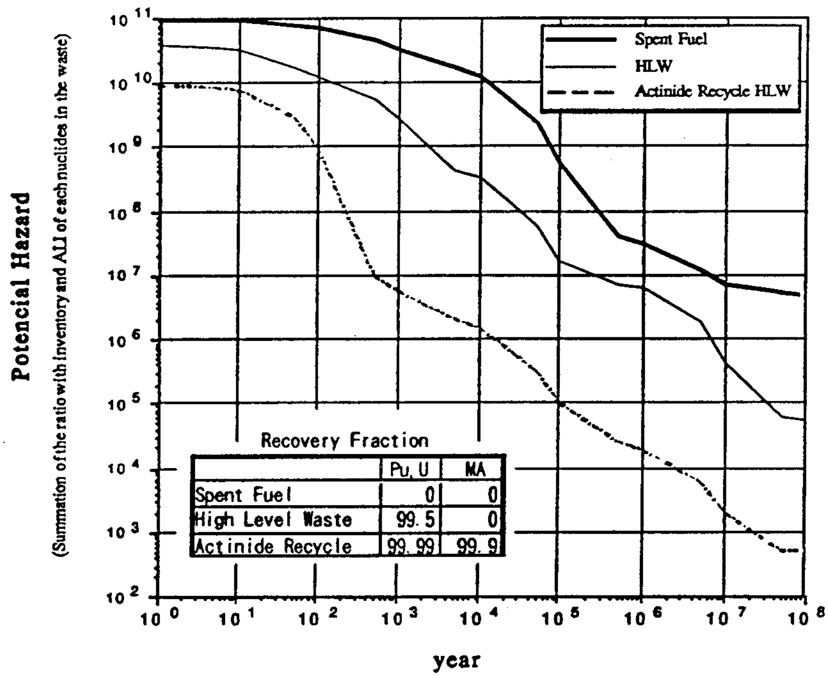

Fig.7 Effect of the Actinide Recovery on the Potencial Hazard of FBR-HLW (150,000MWD/t)

5. Conclusions

The development of advanced fuel recycling is expected in the next generation technology to incorporate various purposes such as to reduce the burden to global environment, improvement of economy and additional proliferation resistance. By recycling MA into commercial FBR, the MA existed in fuel cycle is reduced by 80% of no-recycle value. The long-lived radiotoxicity is reduced by recovering MA and reducing Pu losses in the fuel cycle.