HIGH LEVEL WASTE PARTITIONING AS AN OBLIGATORY PART OF THE USED NUCLEAR FUEL MANAGEMENT

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Abstract

Minimizing the volume of nuclear energy waste becomes more and more vital issue year by year. In many countries, the solution of this problem is a corner stone for taking decision on new nuclear build and for dilemma either to extend the national nuclear energy program or to phase out. Rosatom pays special attention to development of technologies aimed at activity and volume reduction for radioactive waste (including HLW) which is subject to final disposal, especially in terms of fractioning HLW resulting after spent nuclear fuel processing.

1. BACKGROUND

Currently, high level rafinates (hereinafter referred to as HLW) are generated during the industrial SNF reprocessing process. Final stage of HLW management is vitrification. Vitrified HLW must be disposed in the deep geological repository (depth is more than 300 m) after the interim storage (more than 10 years) for decay heat reduction. Successful scale up of SNF reprocessing depends on safety aspects and total price of radioactive waste volume reduction. Advanced technology of SNF treatment eliminates the requirement of deep geological disposal because of HLW partitioning and following separate management of different fractions. The basic idea of deep HLW partitioning is extraction of long-lived and radiotoxic nuclides. It allows to direct the extraction fraction to transmutation, Cs and Sr fraction (in form of vitrified ILW) to near surface disposal after the interim storage on the period of 100 – 350 years. This solution helps to reduce the cost of deep geological repositories construction more than 10 times, at the same time to increase SNF reprocessing capacity. Sr and Cs fraction should be vitrified (0.2 m3 per 1 ton of SNF) and storage on the period of 350 years till the specific activity reduction (till the intermediate level of activity). It seems appropriate to vitrify Eu and Sm fraction together with Cs and Sr fraction, because of it needs the 100 years of interim storage too. Other part of rare earth elements must be vitrified together with fission products (1.0 m3 per 1 ton of SNF), storage on the period of 50 years, after that this vitrified waste will not be classified as radioactive. There are two possible ways for Zr fraction: i) to connect with high level solid waste (fuel assembly caps, cladding fragments, precipitate of zirconium molybdates), ii) to solidify in the low concentration to be classified as a very low level non-radioactive waste (20 m^3 per 1 ton of SNF).The same solution for Th fraction - solidification (25 m3 per 1 ton of SNF) to be classified as a very low level non-radioactive waste.

2. RUSSIAN EXPERIENS IN HLW PARTITIONING

Development of technologies for the extraction of individual fractions of radionuclides, called "partitioning technology" began in Russian Federation in the late 1970s. The task of partitioning was the HLW processing, providing for pre-extraction and concentration in small amounts of active components with significant decontamination of the ballast RW mass, allowing to solidify it by cheaper methods, for example, cementing followed by surface storage. In addition, during partitioning it is possible and necessary to separate the active components into groups depending on the lifetime of radionuclides and their chemical nature. This will allow in the future to solve the problem of the most long-lived and radiotoxic actinides by transmutation and to use for solidification each group of nuclides special strong matrix.

Below is a brief review of the basic options for the main technologies of acidic HLW partitioning, developed by Russian institutions and tested at Mayak Plant (reprocessing facility), at least on a bench scale:

- extraction technology for strontium and caesium separation by a system based on crown-ethers;
- extraction technology for strontium and caesium separation by a system based on chlorinated cobalt dicarbollide (CCD);
- technology of extraction and separation of rare earth (REE) and trans plutonium (TPE) elements by extraction system based on CCD;
- extraction technology f
- or REE and TPE separation by a system based on multi-radical phosphinoxide (MRPHO);
- extraction technology for REE and TPE separation by a system based on carbamoyl phosphinoxide (CMPHO);
- extraction technology for REE and TPE separation by a system based on tetractinellida diglycolic acid (TODGA);
- separation of REE and TPE by a method based on a complexing chromatography on sulfocationite;
- sorption extraction of cesium using inorganic electron-ion exchanger-potassium-copper ferrocyanide (FS-10).

Two technologies based on chlorinated cobalt dicarbollide (CCD) and crown-ethers were considered as the main ones. The most developed and reached the level of pilot operation, was the extraction system based on CDK. Initially, as the extractant was used CDK in a mixture of orthochlorotoluene (OCHNB), hexachlorobutadiene (HCHBD) and polyethylene glycol. This extraction system after numerous laboratory and bench tests at the end of 1980 was tested on a pilot partitioning at the RT-1 (Mayak Plant). More than 450 m3 of HLW of different composition was processed at this plant. Successful pilot testing of partitioning technologies has allowed to create a pilot plant. It has received the code name – UE-35.

Since 1999, all current refined products from the UE-35 plant were processed by oxalate deposition of TPE and REE to remove alpha-emitters.

Since 2003, the reextract of cesium and strontium of the UE-35 plant have been partially used for the manufacture of cesium-137 sources in the isotope production of Mayak Plant.

In 2015, in conjunction with institutes of the Russian Academy of Science conducted the successful test of two-stage technology of extraction of Cm-244 and Am-241,243 from REE and TPE concentrate. As a result of the refining process, about 14 g of curium-244 was separated, of which 9 g was a fraction of enriched curium with an americium content of less than 6% by activity. In a mixed fraction of curium-americium, there were approximately 4.65 g of Cm-244 and 40 g of Am-241,243. In the enriched fraction of americium, the curium content was less than 0.8% by weight, and the europium-154, 155 content was less than 0.1% by activity.

Currently, works are continuing to improve technologies and develop equipment for the implementation of HLW partitioning on an industrial scale.

3. CONCLUSIONS

- New nuclear fuel cycles requires change in attitude to the high level radioactive waste: it should be partitioned following separate treatment of the different fractions;
- Advanced radiochemistry technologies are demanded. The first steps are made;
- Finally the only intermediate radioactive waste could be produced at Nuclear Fuel reprocessing. No need for the deep geological disposal in this case;
- Respective benefit in the Nuclear Fuel Cycle total cost is coming.