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Evaluation of Metal Waste Inventory from Pyroprocessing of PWR Spent Fuels for a Deep Geological Disposal System Design

Dong-Keun Cho, DongHak Kook, Jongwon Choi, and Heui-Joo Choi
Korea Atomic Energy Research Institute

1. Introduction

There are currently twenty nuclear power plants in operation in Korea. It is estimated that approximately 700 tons of uranium is produced annually. The amount of stockpiled spent fuel was announced to be 10,761 tons at the end of 2009 [1]. 'The 3rd Comprehensive Nuclear Energy Promotion Plan' [2], passed at the 254th meeting of the Nuclear Energy Committee, announced a future R&D plan on the development of pyroprocessing in connection with a sodium fast reactor for a reduction in the amount of spent fuel and a sustainable stable energy supply. The amount of spent fuel can be remarkably reduced through a recycling process where transuranics (TRUs) are burned in a fast reactor, and where Cs and Sr are disposed of after sufficient interim storage to make the eventual decay heat of radwaste at the final repository trivial [3].

For a case where the direct disposal of spent fuel is considered, the source terms of the assembly hardware are clearly not important, as they are mainly induced from actinides and fission products (FPs) in irradiated fuel, with a yield of approximately 99%. However, in an advanced fuel cycle using the recycling mentioned above, the source terms of the assembly hardware, i.e., metal waste from the pyroprocessing, can be important in the disposal system design.

In this paper, the inventory of metal waste from the pyroprocessing of domestic spent fuel was estimated for a deep geological disposal system design.

2. Boundary Conditions

2.1 Spent Fuel Arising

According to the '4th Basic Plan on Electricity Supply and Demand" [4], 32 nuclear power plants will be operational in Korea by 2022, resulting in 4 CANDU and 22 PWR reactors. This plan will give nuclear power a 47.9% share in electricity generation in Korea, with 32,916 MWe of nuclear installation capacity.

In this study, the total projected amount of spent fuel based on the '4th Basic Plan on Electricity Supply and Demand" was used as a basis in the estimation of metal waste inventory that should be disposed of in a deep geological repository. When the amount of spent fuel arising from this plan was estimated, it was assumed that 18.1 ton-Uranium (tU), 19.2 tU, and 26.2 tU would be produced annually for Westinghouse type, OPR 1000, and APR 1400 reactors, respectively. For Kori units 1 and 2, 13.1 tU and 16.1 tU were assumed, respectively. All PWRs were assumed to have a 60-year operational period except Kori unit 1, which was assumed to have a 50-year operational period. As a result, the amount of spent fuel to be produced was shown to be 36,400 tU from the existing and planned PWRs.

2.2 Reference Spent Fuel

A variety of spent fuel types have been generated as the technology to improve neutron economy, corrosion resistance, and mechanical integrity has developed. Approximately 16 types of assembly design are already produced from commercial PWRs. It is heavily burdensome to consider all spent fuel assembly types to define the metal waste inventory for a deep geological disposal system design. In this study, a 17×17 KOFA design was used as a reference spent fuel assembly.

When 10 tons of uranium initially loaded into approximately 23 spent fuel assemblies are pyroprocessed, the waste amounts contaminated by U, TRUs, and FPs are 2.51 tons, while the amount of only neutron-activated waste without contamination (hereafter, 'noncontaminated waste') is 0.72 tons. Most of the contaminated waste consists of Zry-4 cladding, at 2.46 tons, and the remainder consists of SUS 302 plenum springs. Noncontaminated waste consists of 365 kg of Zircaloy-4 grid plates and guide tubes, 30.8 kg of Inconel 718 grid plates, 124.6 kg of SUS 321 bottom-end pieces, 144.3 kg of SUS 321 top-end flow plates and frames, and 34.1 kg of top-end leaf springs.

3. Results

3.1 Specific Activity of Metal Waste

The specific activity for each component was calculated using the ORIGEN-S code [5]. Next, the specific activity of the key nuclides in each waste component was then compared with Korean acceptance criteria for low- and intermediate-level waste (LILW) repositories to judge what structural components should be classified as waste for deep geological disposal. When the calculation was done, the composition was taken from reference 6 and from built-in data in ORIGEN2.1

From the analysis, for a case where neutron-activated source terms of noncontaminated waste are considered, Inconel grid plates, SUS plenum springs, SUS guide tube subparts, and Inconel top-end leaf springs were shown to be waste types requiring disposal in a deep geological repository.

Along with these contaminated waste types, Zircaloy cladding contaminated by actinides and FPs during the dissolving stage of pyroprocessing was also revealed to be waste requiring a deep geological repository, as it has 2 and 52 times higher the specific activity than the limit values for ^{90}Sr and alpha contamination, respectively. Figures 1 and 2 show the specific activities of key nuclides related with the acceptance criteria for the waste class for neutron-activated Zry cladding and FP and actinide contaminants, respectively.

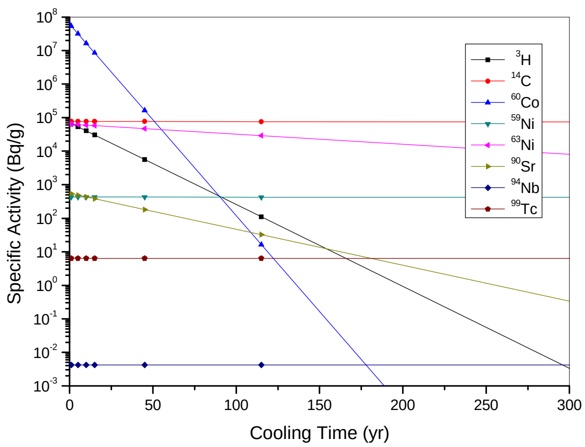

Fig. 1. Specific activity of Zry cladding

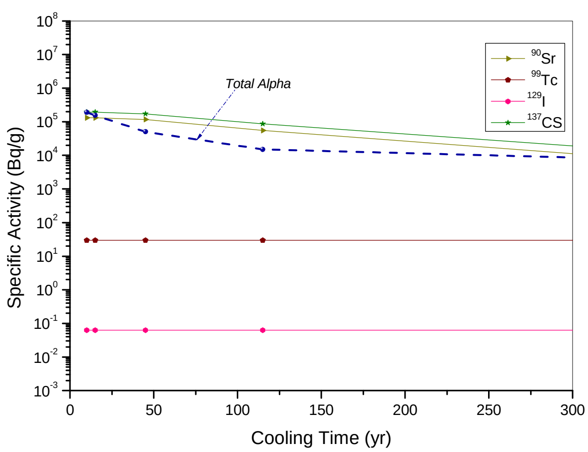

Fig. 2. Specific activity of FP and actinide contaminants

3.2 Inventory of Metal Waste for a Deep Geological Repository.

From the above analysis, it was found that 2.7 tons of structural components should be discarded in a deep geological repository, when 10 tons spent fuel uranium are pyroprocessed.

Considering that 36,400 tU will be produced from existing and planned PWRs on the basis of the current national plan, it can be summarized that 9,800 tons of metal waste will be produced requiring a deep geological repository.

It should be noted that for the inventory of metal waste for a deep geological repository, all spent fuel assemblies are assumed to be of a 17×17 KOFA fuel design. However, as mentioned earlier, 16 kinds of fuel designs were generated from existing PWRs. These fuel designs have different configurations and compositions in terms of assembly hardware. Therefore, further consideration should be carried out for a more reliable inventory estimation of metal waste beyond LILW.

4. Conclusions

In this paper, the inventory of metal waste to be accommodated in a deep geological repository was estimated based on a 17×17 KOFA fuel design. First, the spent fuel inventory to be produced from existing and planned PWRs was projected on the basis of a national plan. Next, classification of waste materials based on the pyroprocessing of 10 tons of uranium was carried out. Finally, considering the projected amount of spent fuels, 36,400 tU, it was found that 9,800 tons of metal waste will be produced as waste for a deep geological repository. Further studies on all types of assembly designs are on-going.

ACKNOWLEDGEMENTS

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