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EFFECT OF METALLIZATION ON PERMANENT DISPOSAL OF HLW

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Abstract

To solve the burden of disposal of spent nuclear fuel, many alternatives are studied. One of the prominent option is the metallization. Throughout the metallization, major nuclides producing decay heat are separately and solidified. All TRU' s remain in the Li reduction facilities and form a metal ingot. The solidified wastes are to be stored above ground until decay heat becomes significantly reduces. Metal ingots are disposed into an underground repository. Results show that the metallization can save the area of a potential repository by 60%. Also, removal of a gap in a spent nuclear fuel through the metallization process can decrease the doses significantly.

I. Background

To the present generation enjoying cost effective and sustainable nuclear energy, followings are critical ethical responsibilities for closing the back end nuclear fuel cycle, radioactive waste disposal:

1) The present generation should bear all economical cost for closing the nuclear fuel cycle based on the polluter' s pay principle.
2) Long term safety of a repository should be proved to relieve any burden of future generations as low as reasonably achievable, and
3) The permanent disposal of HLW should solve the nuclear proliferation issue.

According to the preliminary design of a generic repository for permanent disposal of HLW, which will be inaugurated in the middle of this century, Korea needs the area of approximately four square kilometers to dispose of 36,000 MT from 28 nuclear power plants to be in operation or to be retired before 2015. The most preferable host rock considering geological characteristics is a crystalline rock such as granite. The crystalline rock is known to have a network of fractures, the most feasible pathway for the transport of radionuclides after failure of a waste container.

When considering the ever-expanding nuclear program in Korea, the total amount of spent nuclear fuel in the future beyond will be enormous. As the volume of spent fuel and the size of a repository increase, the chance to meet a major fracture zone increases. Also, a bigger size repository might cause an additional problem to secure any candidate sites during the process of site selection. Therefore, if economically feasible, it is worthwhile to develop an innovative concept to reduce the size of a potential repository.

II. Environmental Impact of the Pre-Disposal Treatment Process

KAERI has worked on developing the pre-treatment concept based on the Lithium induced reduction process as shown in Figure 1. It is not yet determined whether this technology will be combined to the pyro-processing and then ultimately to transmutation or not. Instead, KAERI would like to identify whether this innovative process will give enough benefit on the permanent disposal of HLW, still satisfying three key ethical principles presented at the beginning of this paper. The current concept separates nuclides with high decay heat from others. Most long lived nuclides inclusive of TRU's forms a metal ingot. The rest of radioactive wastes inclusive of heat generating nuclides such as Sr-90 and Cs-137 in the form of molten salt is solidified and stored above ground for a certain time enough to cool down the decay heat before final disposal. The metal ingot will be disposed of into a repository ultimately. This pre-disposal treatment process alters the content of radioactivity and heat. When key heat producing nuclides are removed then the profile of the heat flux of a metal ingot is changed as shown in Figure 2.

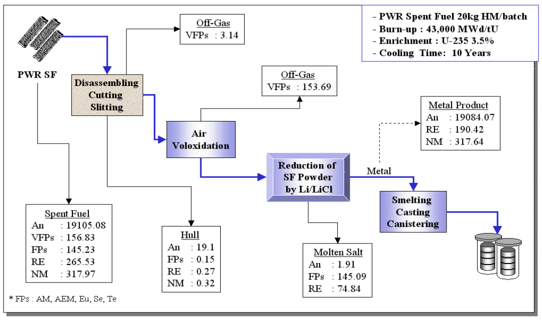

Figure 1. Overview of the Metallization Process

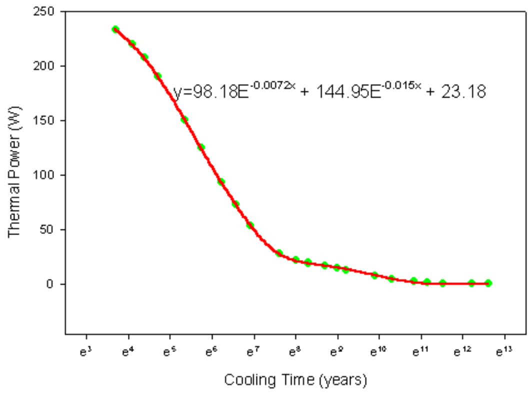

Figure 2. Profile of Decay Heat

Since the bentonite is to be applied as a buffer material to fill a void between a deposition hole and a surrounding rock, to avoid any phase change of bentonite, which significantly reduces the capacity of sorption, the maximum temperature in a buffer should not exceed 100 ^{0}C.

The current direct disposal concept requires the spacing between tunnels and deposition holes as forty and six meters respectively to accommodate four PWR assemblies in a waste container. According to the thermal analysis as shown in Figures 3-4, the pre-treatment concept can reduce the required area for a repository at least by sixty percent. Therefore, the introduction of the pre-treatment will give more flexibility for site selection. Also, if Korea can identify a repository site with a size of four kilometers, by introducing the pre-treatment concept, Korea can dispose of all HLW not only from NPP's to be built by 2015 but also from the ones beyond that, so that Korea will be free from any political and financial burden of seeking the second repository.

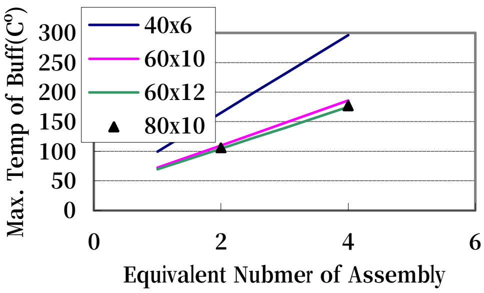

Figure 3. Thermal Analysis for Optimum Layout

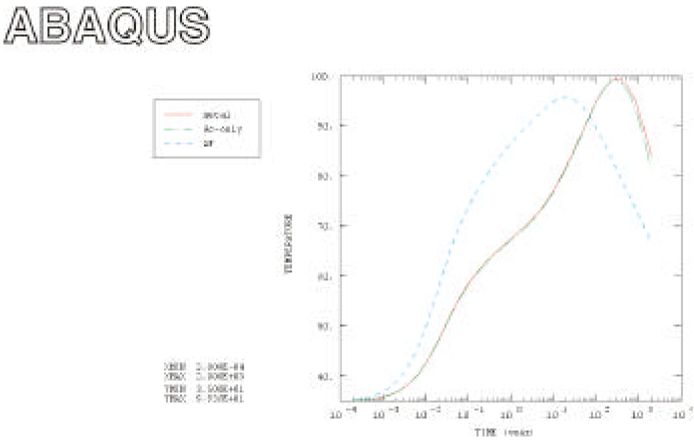

Figure 4. Estimation of the Maximum Temperatures from Three Different Concepts

In addition, the metal transform will alter the release mechanism of radionuclides in a waste container, which also gives a good environmental credit to the pre-treatment process. In spent fuel, a certain portion of radionuclides resides in a void gap between a cladding and a fuel and in a grain boundary. Many of radionuclides are volatile so that when a void gap is filled with intruding groundwater, they do not release from a spent fuel matrix congruently with a matrix itself. Instead, they will be released by so called instantly high release mechanism. KAERI's recent analysis as illustrated in Figures 5 and 6, shows that this release mechanism, by far, is the most critical one in PWR and CANDU spent nuclear fuels. The transformation of HLW will completely homogenize the HLW to remove any void gap and grain boundaries so that the instantly high release of nuclides will not be a post closure safety issue any more. These observations turn out to be a favorable factor for the ethical principle 2 in this paper.

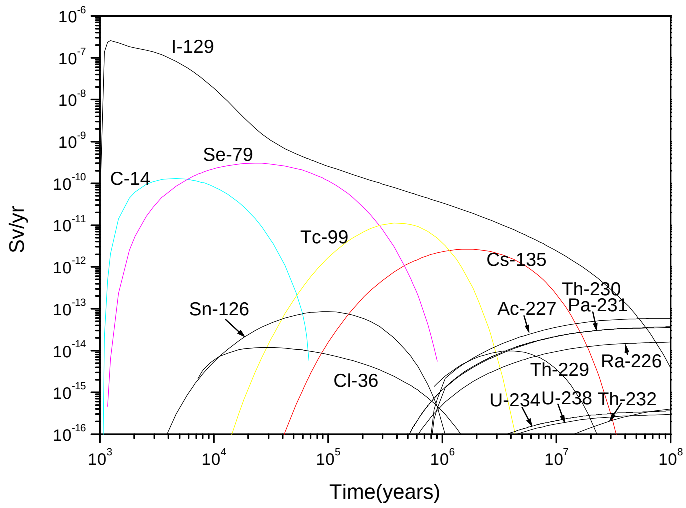

Figure 5. Annual Doses from Direct Disposal of Spent Nuclear Fuel

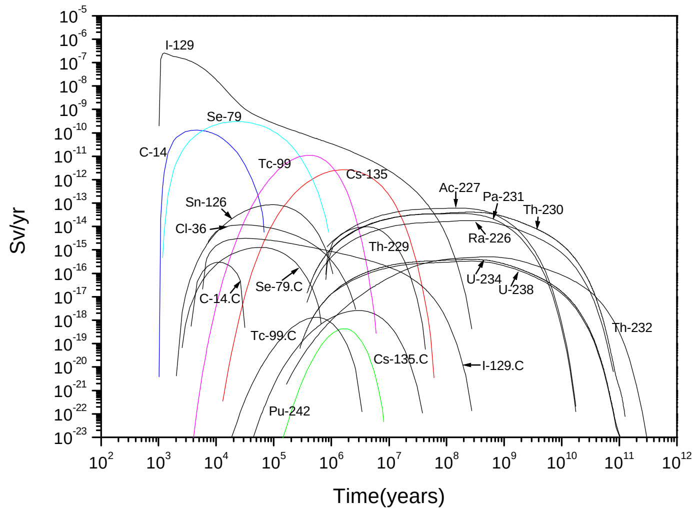

Figure 6. Annual Doses from HLW Disposal by Metallization

In the pre-disposal treatment process, important fissile materials, plutonium-239 and uranium-235 and –233, will be completely mixed up. Therefore, the pre-treatment concept will not deteriorate the ethical principle 3 in this paper.

The remaining issues are the ethical principle 1 and the attitude of a general public. It might be trivial that the proposed pre-treatment concept requires more investment. However, since the technology is at the stage of early development, it is not clear yet how much investment is required to commercialize the facilities. More attention is required to understand the financial aspect of this process throughout the stage of conceptual design of the facilities.

Public perception on this concept might be sharply divided. Firstly, the general public might appreciate the benefit of this process on long-term safety of a repository and easiness to secure a candidate site. However, since it requires the additional above-ground nuclear facilities, it will create another NIMBY syndrome.

KAERI will continuously perform a total feasibility study in the future in cooperation with domestic and international societies. When the feasibility study on the combination of the pre-treatment and disposal of HLW is completed, then the new feasibility study for the entire back-end fuel cycle, from the pre-treatment to permanent disposal of HLW through pyro-processing and transmutation will be initiated.

III. Conclusions

The pre-disposal treatment concept turns out to have some important advantages on permanent disposal of HLW in Korea. Firstly, the thermal flux of the new SF metal solid reduces to ¼ of that from SF. Roughly it reduces the repository volume by 50% compared with that for direct disposal. For countries like Korea with high population density such saving of land will contribute significantly to secure a potential repository.

Also, since it requires less area it will have less probability to meet any major fracture zones in crystalline rocks, a prime candidate for hosting a repository. This will enhance safety of a repository. However, before detailed study, detailed cost analysis is required to identify whether the proposed scheme is economically feasible. Also uncertainties in nuclide inventories will be re-examined and its implication on a repository design and safety will be re-studied in the future.

Acknowledgements

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