ROLE OF P&T ON PERMANENT DISPOSAL OF HLW IN KOREA

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Summary

One of the prime objects of the P&T cycle is to minimise arising of radioactive waste. It is important issue for countries like Korea with high population density and strong NIMBY syndrome. Key issues of P&T on permanent disposal of HLW are discussed focusing on the pre-treatment process, metallisation. Most discussion is focused on two issues: (1) contribution of reducing key elements with high decay heat and (2) contribution of eliminating highly soluble nuclides. The first issue is directly related with the problem of a size of a repository and the second issue is related with environmental impact. The area needed to dispose of all spent nuclear fuels from PWRs and CANDUs is at least around four km^2. It might not be so easy to identify a rock volume with this size without intersecting any major fracture zone unless the traditional KBS-3 concept is altered. To avoid a fracture zone is important not only to enhance safety of a repository but also to relax the burden of siting. Therefore, in the view point of HLW disposal, even a pre-treatment process turns out to relieve a lot of burden on the decaying heat, which is a critical designing constraint for applying bentonite buffer. If the P&T concept is applied, then there will be more significant reduction to the area of a repository. The current KAERI repository concept can dispose of spent nuclear fuels from reactors to be completed by 2015. To dispose of spent nuclear fuel from reactors in the future requires either expansion of a repository area and/or introduction of the second repository. None of these choices might be preferable and the pre-treatment process combined with P&T can contribute significantly to optimise the repository size. The minimisation of the absolute amount of HLW does not tell everything. More importantly, how to get rid of decay heat and high soluble nuclides is the key issue. The longer residence time in a reactor core produces higher decay heat. In worst cases, if the decay heat becomes too high, the current KAERI concept might not be valid any more. In that case, the maximum temperature at the interface between a canister and a buffer region might exceed 100 degree in Celsius so that the retardation capacity of a buffer will be deteriorated. If the P&T cycle in association with metallisation is properly designed this kind of problem can be avoided. The P&T cycle will be one of the prime alternative options to relieve the burden of waste disposal. However, more profound studies are required to investigate the cost benefit effect in the future.

Background

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 km^2 at least, 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 programme 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.

Environmental impact of pre-treatment process of P&T, metallisation process

KAERI has worked on developing the metallisation, 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.

The current concept separates nuclides with high decay heat from others. Most long-lived nuclides inclusive of TRUs form a metal ingot. The rest of radioactive wastes inclusive of heat generating nuclides such as ^{90}Sr and ^{137}Cs 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.

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°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 and 4, the metallisation 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 km, 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 1. **Overview of the metallisation process**

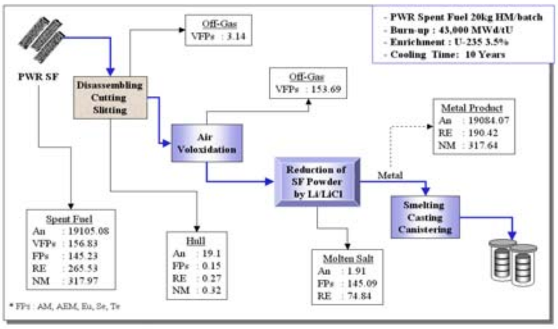


Figure 2. **Profile of decay heat**

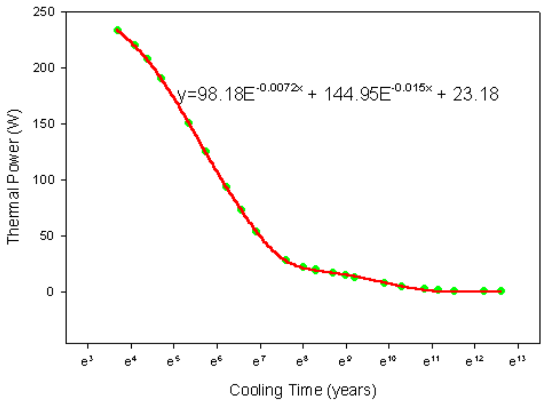


Figure 3. **Thermal analysis for optimum layout**

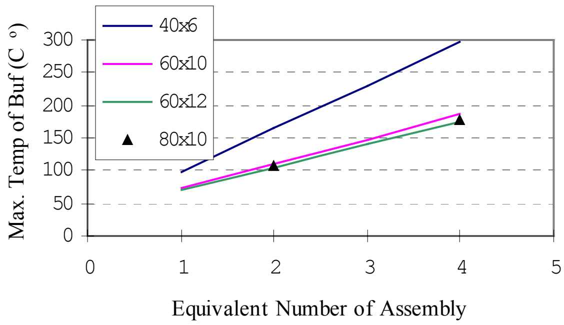
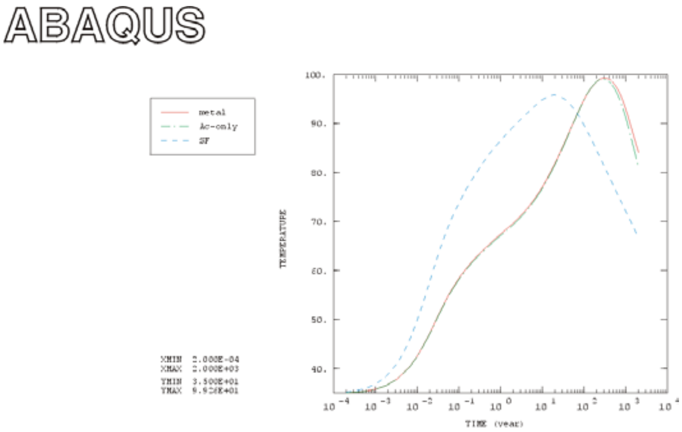


Figure 4. **Estimation of the maximum temperatures from three different concepts**



In addition, the metallisation 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. KAERIs 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 homogenise 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.

Figure 5. **Annual doses from direct disposal of spent nuclear fuel**

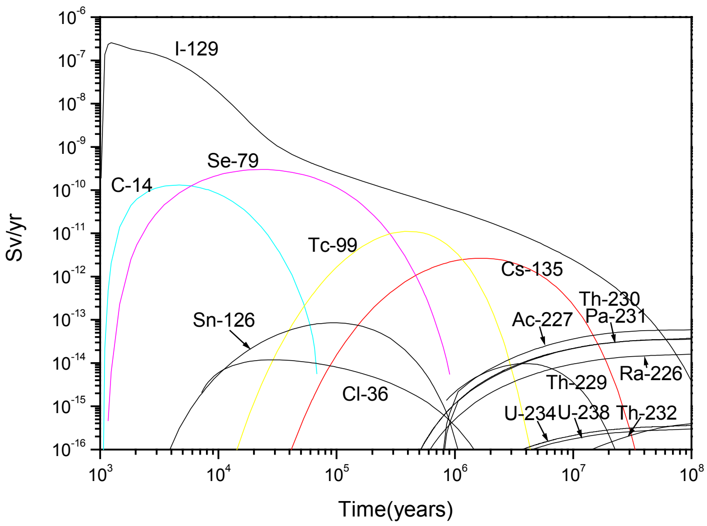
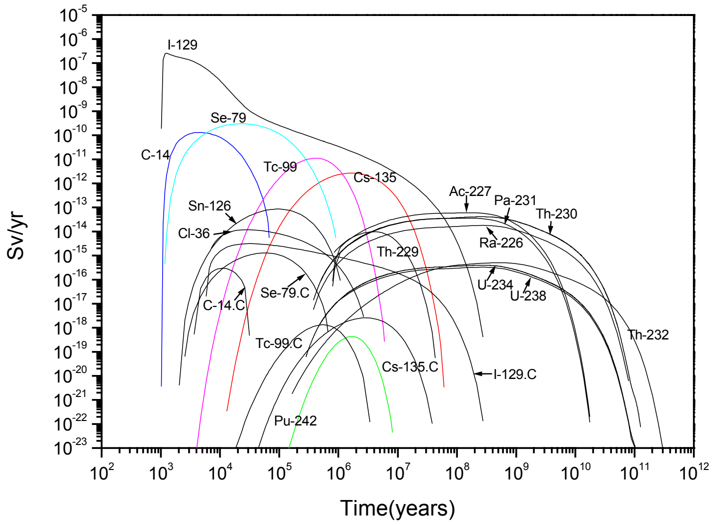


Figure 6. **Annual doses from HLW disposal by pre-treatment process**



It is 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 commercialise 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 co-operation 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.

Conclusions

The pre-treatment process of P&T, the metallisation 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 60% 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

This work is funded by the fundamental R&D project in Korea Atomic Energy Research Institute.