Assessment of the Activation Activity of the Fuel Assembly from Transmutation Reactor-PEACER

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ABSTRACT

The spent nuclear fuel management of current nuclear reactor is one of challenging issues for the continuous utilization of nuclear power. In order to solve this problem, geological disposal has been suggested and studied for decades. But, because of difficulty in finding its highly qualified sites, the partitioning and transmutation (P&T) technology have been introduced as an alternative idea. P&T method of radioactive waste from spent fuel is considered more attractive and gets the much more attention because of the possibility of high public acceptance and better protection of human and our environment and the difficulty in radioactive waste disposal site selection in Korea. Seoul National University (SNU) proposed a new transmutation reactor concept, named as PEACER (Proliferation-resistant Environmental-friendly Accident-tolerant Continuable and Economical Reactor), to convert all the eventual final waste into the form of low-level waste (LLW). The previous study for the waste generated from the PEACER has focused on the feasibility of converting the waste into LLW by the pyroprocess technology and the derivation of the practical value of the decontamination factor (DF) of the future pyroprocessing technology to meet the concentration limit for class C waste of U.S. NRC. In this study, the activation activity of PEACER fuel assembly material which are supposed to the cladding fragments, fuel alloy and grid was evaluated by using theoretical modeling and the corresponding computer code. The material of PEACER fuel assembly is assumed to be made up of HT-9 (including Fe, Cr, Ni, Mn, W). The result of this assessment showed that the main activated radio nuclides are Fe-55($T_{1/2}$=2.6yr) and Mn-54($T_{1/2}$=303day). In order to meet the requirement of the regulation for class C waste of U.S. NRC, the necessary decontaminations applied to the fuel assembly should be greater than 100 times. As reflecting on their short half-life, it is recommended that it could be low-level wastes by on-site cooling more than 12 years.

INTRODUCTION

The spent nuclear fuel of current nuclear reactor is one of challenging issues for the continuous utilization of nuclear power. In order to solve this problem, geological disposal has been suggested and studied for decades. But, because of difficulty in finding its highly qualified sites, the partitioning and transmutation (P&T) technology have been introduced an alternative idea. P&T method of radioactive waste from spent fuel is considered more attractive because of high concern on the public protection and the difficulty in radioactive waste disposal site selection in Korea. Seoul National University (SNU) proposed a new transmutation concept named as PEACER to convert all the final waste into the class of low level waste (LLW).

In order to dispose the final waste from PEACER, The Establishment of Waste Acceptance Criteria for the LLW facility has to be considered first. According to NRC, the human intrusion scenarios determine volumetric concentration limit. On the other hand, the radionuclide migration scenarios impose limit on the total inventory of a radionuclide disposed at the site by means of site specific analysis. The Methodology of NRC traced backward from the dose limit using the human intrusion scenario to find appropriate concentration limit.[1]

PEACER final waste has several special characteristics in establishing concentration limit. It consisted of TRU and LLFP and the mass ratio of each nuclide has been fixed by pyrochemical process. The previous study for waste from PEACER has focused on the feasibility of converting waste into LLW by pyroprocess technology and Practical value of decontamination factor (DF) to meet the concentration limit for class C waste of U.S. NRC.

In this study, the main objective is evaluating the activation activity of the spent fuel assembly and we suggest the derivation of acceptable decontamination factor of metallic wastes and the requirement of metallic wastes management.

METALLIC WASTES FROM PEACER

During the back end fuel cycle stage in PEACER, about 99% of uranium in the LWR spent fuel is assumed to be recovered for the future utilization and all TRU are recycled during the pyroprocess to convert all the final waste into the LLW. Tc-99 and I-129 also are assumed to be separated from waste stream and transmuted to stable nuclide because of their high solubility in water with 95% removal efficiency. In the pyrochemical process, decontamination factor of TRU is introduced as an indicator for the process performance. Overall DF in pyrochemical process is defined as the ratio of mass of loaded TRU into the process to TRU lost into waste stream and expressed as follows:

$$DF = \frac{\text{The loaded TRU into pyrochemical process}}{\text{The lost TRU} \quad \text{into waste stream}} \qquad \text{(Eq. 1)}$$

In the previous study, PEACER pyroprocessing system which assumed to have 10^5 of DF was conceptually proposed[2] and 2.3E+05 of DF was suggested considering several requirements to be satisfied by NRC Class C limit assumed with disposal facility volume 1.6E+05m^3. Figure 1 shows the flow sheet of back end fuel cycle in PEACER.

In order to evaluate the total generated wastes from the pyroprocessing, we assumed that 20 LWR of 1 GWe capacity, 40 years lifetime with spent fuel discharged at 33,000MWD/MTU burnup with 30 years cooling time and 12 PEACER has 60years lifetime. The nuclide inventory by LWR was obtained by ORIGEN2 code. The estimation of generated actinide mass in case of PEACER is analyzed at equilibrium state by REBUS code conducted by Kyoung-hui University, considering the time interval between each process in pyroprocessing. Sr-90, Cs-135, Cs-137 and Sm-151 were assumed to be recovered with 95% removal efficiency during the process to satisfy regulation for heat load and assumed volume of disposal site because of its higher activity and decay heat than the other LLFP’s.

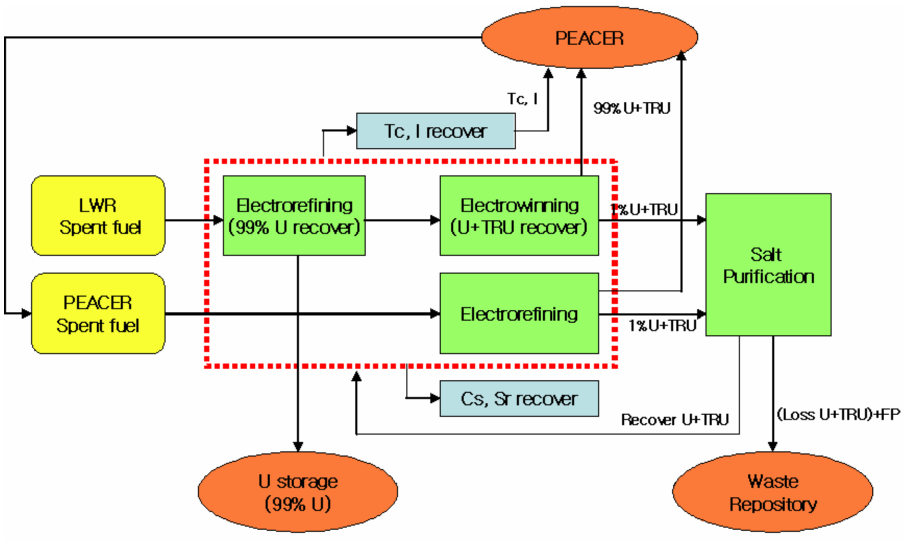

Fig. 1. Flow sheet of back end fuel cycle in PEACER

Assessment of Metallic Wastes

In order to evaluate the activation activity of the spent fuel assembly, we considered the types of metallic waste which is composed of cladding hulls, metallic fission products, grid, plate, spring and guide thimble. At first, we had to know the material and composition of fuel assembly and then the data of the activation activity of spent fuel assembly was calculated by using ORIGEN 2 code. From the results, decontamination requirement was developed to establish the metallic waste management of PEACER.

To develop the requirement of decontamination, we used the regulation of metallic waste NRC 10CFR61.55 Class C Limit on Table I.

Table I. NRC 10CFR61.55 Class C Limit

Radionuclide	Concentration Limit [Ci/m^3]
C-14 in activated metal	80
Ni-59 in activated metal	220
Co-60	700
Ni-63 in activated metal	7000
Nb-94 in activated metal	0.2
Total of all nuclides with less than 5 year half-life	700

The material of PEACER fuel assembly is assumed to be made up of HT-9 (including Fe, Cr, Ni, Mn, W). Figure 2 shows the material composition of HT-9.

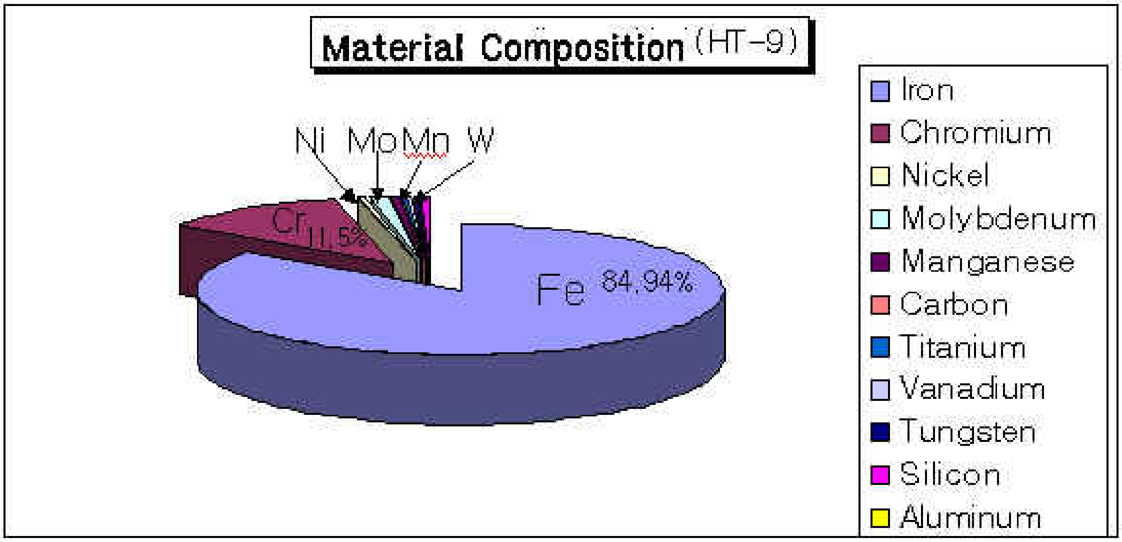

Fig. 2. Material composition of PEACER fuel assembly (HT-9)

Results of Activation Activity of Spent Fuel Assembly

We assumed the spent fuel generated from 300 MWth irradiation of core average flux and 3 batch irradiation. The generation volume is evaluated by using the production per year. Figure 3 shows the results of activation activity of spent fuel assembly of PEACER.

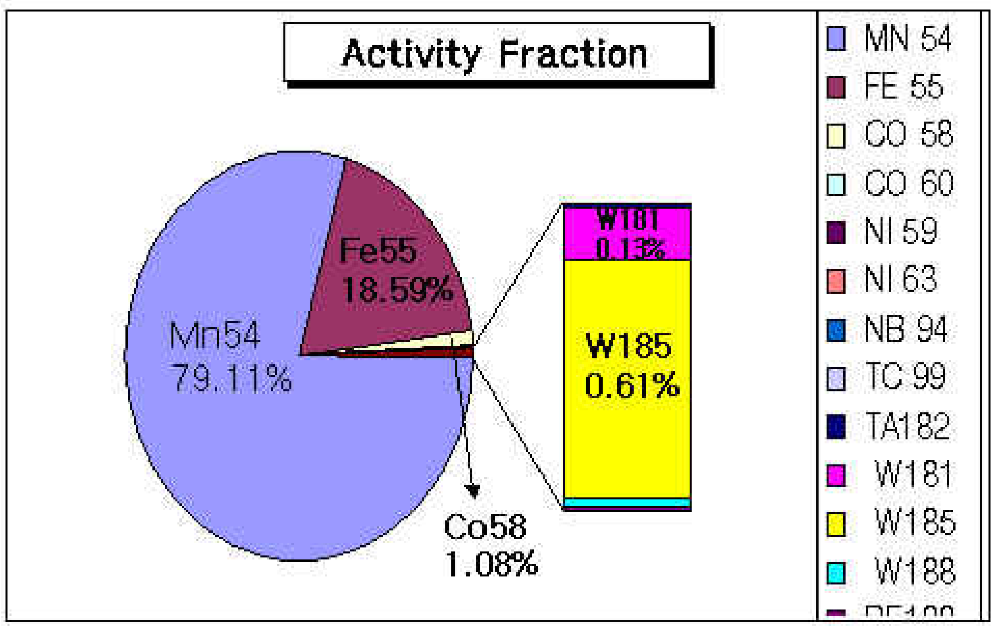

Fig. 3. Activity fraction compare to regulation

The result of this assessment showed that the main activated radio nuclides are Fe-55($T_{1/2}$=2.6yr) and Mn-54($T_{1/2}$=303day).

Evaluated activity has to meet the NRC classification rule of sum of the activity fraction rule for mixture as following:

$$\sum_{i+1}^{n} \frac{C_i}{CL_i} \leq 1.0 \qquad \text{(Eq. 2)}$$

Figure 4 shows the activity fraction of spent fuel assembly in a point of view on the classification rule.

From the results, in order to meet the regulation for class C waste of U.S NRC, necessary decontaminations applied to the spent fuel assembly should be greater than 100 times.

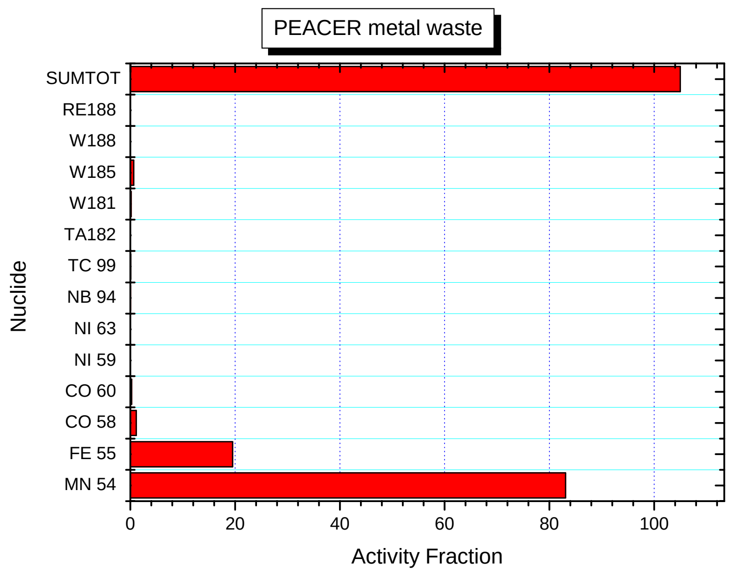

Fig. 4. Activity Fraction

We can consider the options to meet the regulation of metallic wastes to be low level waste as following :

1. Implementation of physical & chemical decontamination
   - ⇨ Need for the additional cost and space because of decontamination facility
   - ⇨ Difficulty of the selective decontamination
2. (metallic wastes are mixed with various radio nuclides)
3. Dilution by waste stabilization after F.A chopping
   - ⇨ Increase of waste volume (> 1.12E+03 m^3) and load of disposal facilityRequire more higher recovery yield of pyroprocessingOn-Site Cooling (decay of activity)
   - ⇨ relatively short half life of main radio nuclides
5. : Fe-55(2.6yr), Mn-54(303d), Co-58(71.3d)it is strongly recommended (low cost & technology)

Figure 5 shows the effect of activity decay by on-site cooling of spent fuel assembly and the guide line to meet the regulation of classification rule.

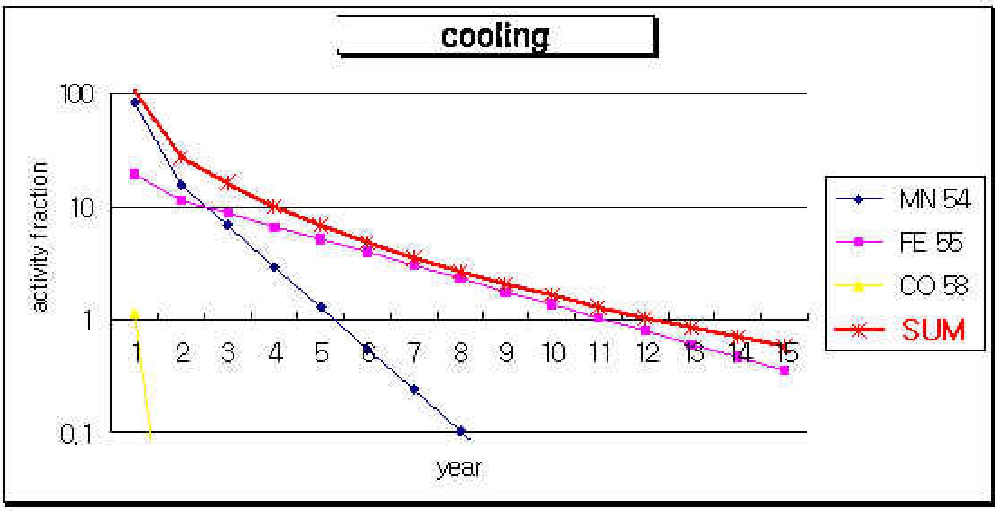

Fig. 5. On site cooling of spent fuel assembly

CONCLUSION

In this study, the activation activity of PEACER fuel assembly material which are supposed to the cladding fragments, fuel alloy and grid was evaluated by using theoretical modeling and the corresponding computer code. The material of PEACER fuel assembly is assumed to be made up of HT-9 (including Fe, Cr, Ni, Mn, W). The result of this assessment showed that the main activated radio nuclides are Fe-55($T_{1/2}$=2.6yr) and Mn-54($T_{1/2}$=303day). In order to meet the requirement of the regulation for class C waste of U.S. NRC, the necessary decontaminations applied to the fuel assembly should be greater than 100 times. As reflecting on their short half-life, it is recommended that it could be low-level wastes by on-site cooling more than 12 years.

ACKNOLWLEDMENTS

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