Preliminary Assessment of Radioactive Waste for the DEMO Fusion Reactor

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Abstract

In order to assess the fusion radioactive waste, activation characteristics have been analyzed for the main three modules of ITER model. By choosing irradiation and cooling scenarios, the activation calculations were performed by FISPACT 2007 code. Neutron flux distributions in the fusion reactor were provided by a MCNP calculation. The design of the DEMO fusion reactor is referred from ITER model. The calculated fluxes were employed to FISPACT for the activation calculation. As a result, the total activities and total decay heats for the three main modules of the fusion reactor (TBM, Vacuum Vessel, and Diverter) were calculated and analyzed. The module which gives the highest total activity right after shutdown of the reactor was the Diverter. However the total activity at the TBM after one year shows higher than that of the Diverter. The activation inventory and the main radioactive materials at every cooling time step were obtained for each one of the modules. Finally, the quantitative assessments of the fusion radioactive wastes were performed in comparison with the fission radioactive waste of Korean NPP.

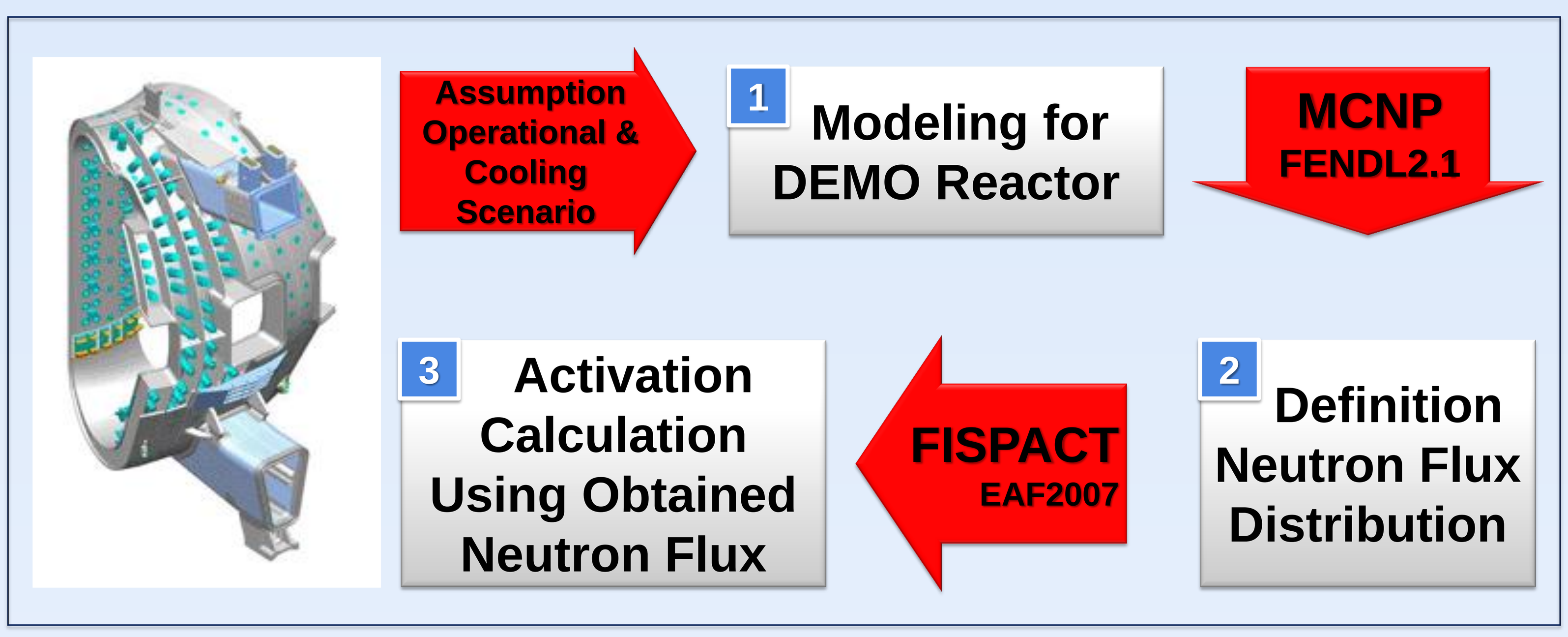
I. Introduction

- The nuclear fusion reactor would not be produced the high-level radioactive spent fuel as like as fission reactors.
- Medium or low level radioactive wastes which are produced when the fusion reactor is operated or decommissioned are expected to be non-negligible magnitude.
- It is necessary to perform the quantitative assessments of the fusion radioactive wastes.

This process would be referred to make the regulation for the construction of DEMO fusion reactor which is planning for construction as a future work in Korea.

II. Objective

For Three Main Modules of Demonstration Reactor(DEMO)



Assessment of Radioactive Waste for the DEMO Fusion Reactor

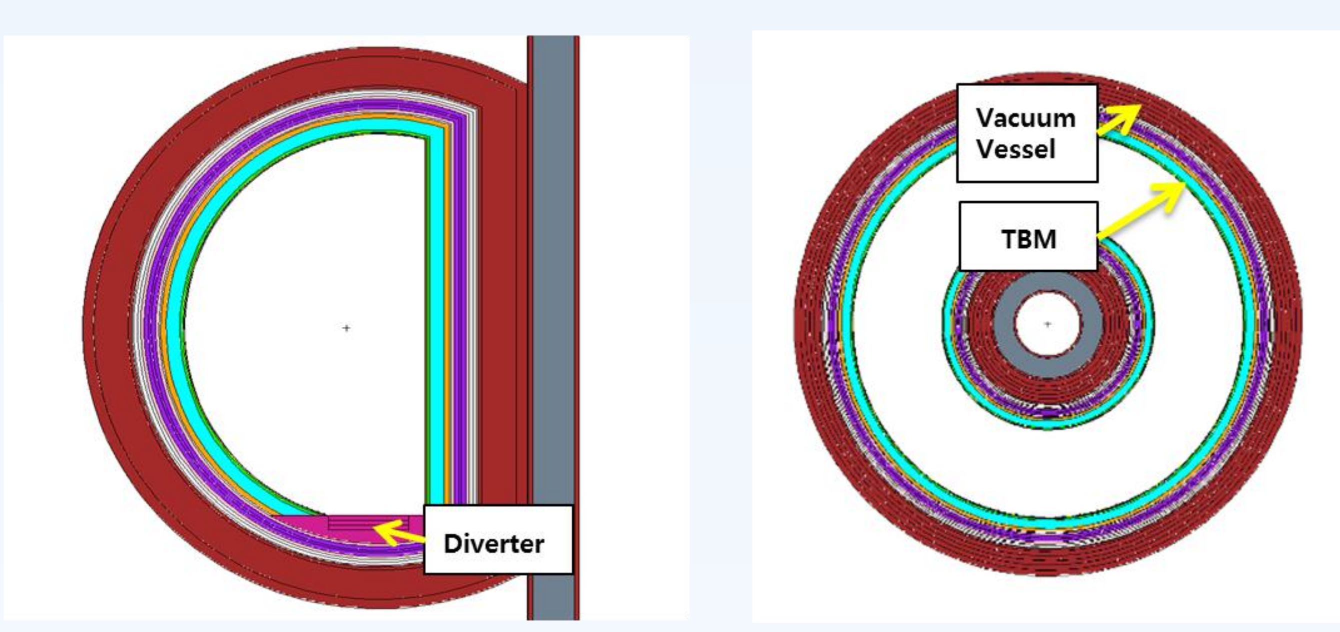
III. Methods

1. Operational and Cooling Scenario

- Fusion Reactor Size – ITER size is refferred
- Electric Power – 1000 MW
- Effective Full Power Day (EFPD) – 300
- Cooling Time After Shutdown – 100 year
- Time Step During Cooling
  - 1 sec, 1 hour, 10 hours, 1 day, 5 days, 7 days, 20 days, 50 days, 3 months, 1 year, 5 years, 20 years, 50 years, 100 years

2. MCNP Simulations

- MCNP Modeling - Simplifying Three Main Module of Fusion Reactor for Assessment of Radioactive Waste



MCNP Modeling of Diverter, Test Blanket Module, Vacuum Vessel

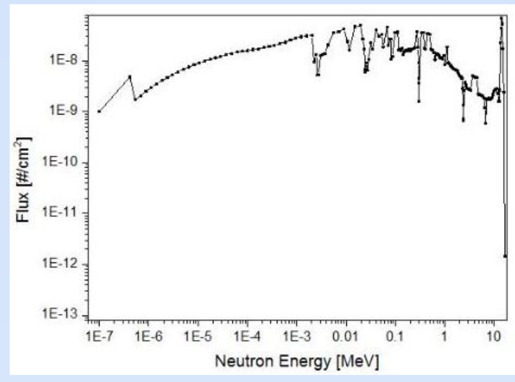
- Neutron Flux Calculation at Three Main Module

3. Activation Calculation using FISPACT+EASY2007

- Using the obtained neutron flux and activation parameter, the activation inventory and activity of each module are calculated at all time step
- Deuterium and tritium aren't considered.
- The materials which have low activity and short decay time are excepted.

IV. Results and Discussion

1. Neutron Flux at Three Modules by MCNP Calculation



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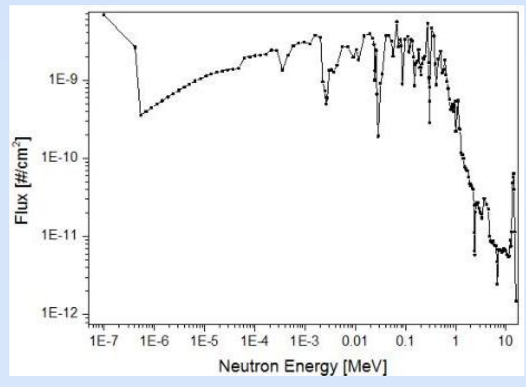
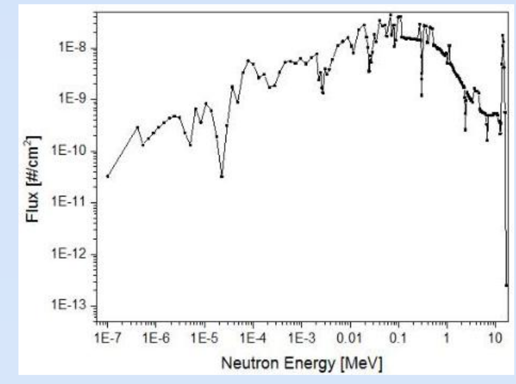
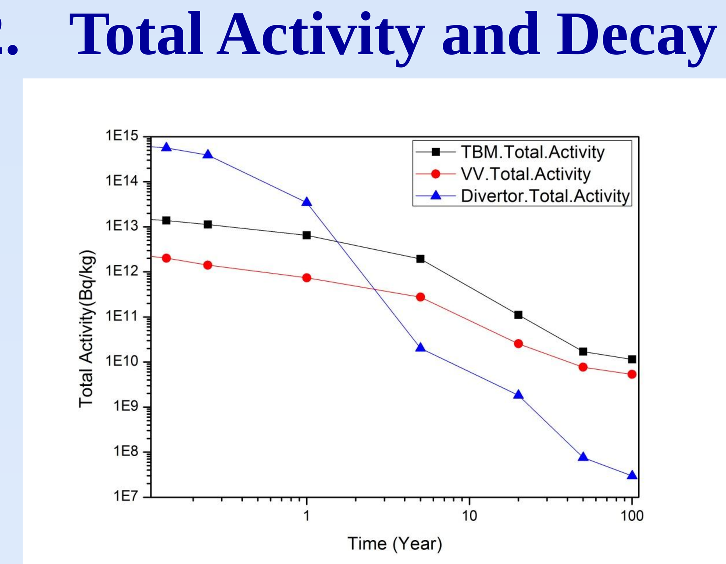


<Vacuum Vessel>

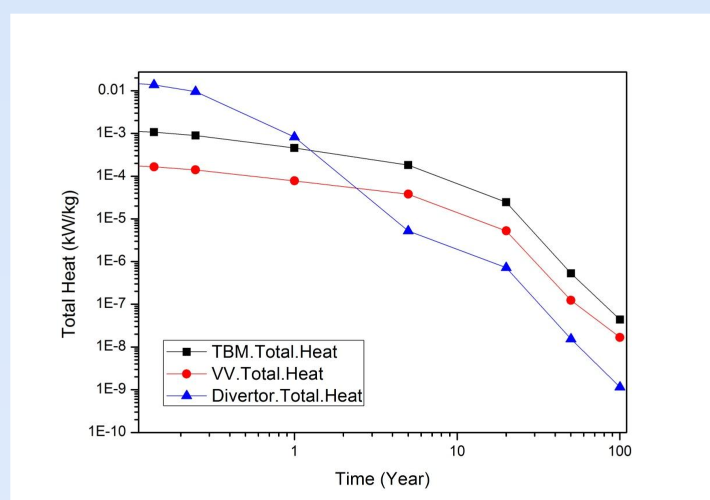


<Diverter>

2. Total Activity and Decay Heat



<Total Activity of Three Modules>



<Total Decay Heat of Three Modules>

- Until one year after shutdown, the total activity and decay heat at diverter are highest.
- The total activity at the TBM after one year shows higher than that of the Diverter.
- The results show that at 100 year cooling time after shutdown the total activity is 1.53×10^{12} Bq/kg and 1.82×10^{9} Bq/kg for TBM and Diverter, respectively.

3. Radioactive Material Inventory

- The activation inventory and the main radioactive materials at every cooling time step were obtained for each one of the modules.

1sec	1hr	10hr	1day	5day	10day	20day	50day	90day	1yr	5yr	20yr	50yr	100yr
Cu64	Cu64	Cu64	Cu64	Co60	Co60	Co60	Co60	Co60	Co60	Co60m	Co60m	Co60m	Co60m
Co60	Co60	Co60	Co60	Cr51	Cr51	Cr51	Cr51	Cr51	Cr51	Co60	Co60	Co60	Co60
Cr51	Cr51	Cr51	Cr51	Co58	Co58	Co58	Co58	Co58	Co58	Co58	Ni63	Ni63	Ni63
Co58	Co58	Co58	Co58	Y89m	Y89m	Y89m	Fe59	Fe59	Fe59	Ni63	V49	Y90	Y90
Y89m	Y89m	Y89m	Y89m	Zr89	Zr89	Zr89	Ni63	Ni63	Ni63	V49	Y90	H3	H3
Zr89	Zr89	Zr89	Zr89	Fe59	Fe59	Fe59	Zr95	Zr95	Zr95	Y90	Zn65	Fe55	Sr90
Fe59	Fe59	Fe59	Fe59	Ni63	Ni63	Ni63	V49	V49	V49	Nb95	H3	Sr90	C14
Ni63	Ni63	Ni63	Ni63	Zr95	Zr95	Zr95	Nb95	Y90	Y90	Zn65	Co57	C14	Zr93
Zr95	Zr95	Zr95	Zr95	V49	V49	V49	Zn65	Nb95	Nb95	H3	Fe55	Zr93	Ni59
V49	V49	V49	V49	Y90	Y90	Nb95	H3	Zn65	Zn65	Co57	Sr90	Ni59	Nb93m
Y90	Y90	Y90	Y90	Nb95	Nb95	Zn65	Y91	H3	H3	Y88	C14	Nb93m	Fe60
Nb95	Nb95	Nb95	Nb95	Zn65	Zn65	H3	Sr89	Y91	Y91	Fe55	Zr93	Fe60	Nb94
Zn65	Zn65	Zn65	Zn65	H3	H3	Y91	Nb95m	Sr89	Sr89	Mn54	Ni59	Nb94	Kr85
H3	H3	H3	H3	Y91	Y91	Sr89	Co57	Nb95m	Nb95m	Sr90	Nb93m	Kr85	Be10
Y91	Y91	Y91	Y91	Sr89	Sr89	Nb95m	Y88	Co57	Co57	C14	Fe60	Be10	Tc99
Sr89	Sr89	Sr89	Sr89	Nb95m	Nb95m	Co57	V48	Y88	Y88	Zr93	Nb94	Tc99	Mo93
Nb95m	Nb95m	Nb95m	Nb95m	Co57	Co57	Y88	Fe55	Fe55	Fe55	Ni59	Kr85	Mo93	Al26
Co57	Co57	Co57	Co57	Y88	Y88	V48	Mn54	Mn54	Mn54	Nb93m	Be10	Al26	P32
Y88	Y88	Y88	Y88	V48	V48	Fe55	Sc46	Sc46	Sr90	Fe60	Tc99	P32	Si32
V48	V48	V48	V48	Fe55	Fe55	Mn54	Zr88	Zr88	C14	Nb94	Mo93	Si32	Zr94

<Radioactive Material Inventory for TBM>

4. Solid Type Radioactive Waste

- At Fusion Reactor - Changeable Module(TBM, Diverter)
- At Nuclear Power Plant - Spent Fuel

Korean NPP		Demo Fusion Reactor			
		Blanket Module		Diverter	
Radioactive Materials	Total Activity (Bq/kg)	Radioactive Materials	Total Activity (Bq/kg)	Radioactive Materials	Total Activity (Bq/kg)
Uranium	1.86E+09	Ni63 Co60	1.53E+12	Co60 Re186 Ta182 Nb93m	1.82E+09
TRU	5.19E+13				
Noble Metal	1.13E+12				
Rare Earth	4.32E+13				
Alkali Metal	5.57E+13				
Alkali Earth	8.40E+13				
Others	1.56E+10				
Total	2.36E+14				

- Annual Radioactive Waste Disposal
  - Fusion Reactor : ~ 1950 tons, **but medium or low level**
  - Fission Reactor : ~ 15. 6 tons, **but high level and long decay time**

V. Conclusions

- In this paper, the activation characteristics of DEMO were presented and discussed.
- Consequently, because of **the low-level radioactivity and short decay time**, the radioactive waste of fusion reactor is **more convenient to dispose** than that of NPP despite the quantity of fusion radioactive waste is tremendous.