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Preliminary Core Design for Thorium Based Gas Cooled Reactor

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1. Introduction

- **Within the development of nuclear reactors, engineers made a lot of attempts to increase the efficiency of the energies to generate electricity, and to decrease the amount of high-level radioactive waste from the nuclear reactors.**
- **The main purpose of this paper is to build long life thermal reactor using thorium, and make thorium fueled fast reactor which does not change the geometry a lot from the reference model of core design.**
- **The core design and various calculations was performed with MCNP 6.2, and visualized with Visual Editor.**

2. Analysis

- **Design parameters of Gas Cooled Reactors**

Design Parameters	Gas Cooled Thermal Reactor	Gas Cooled Fast Reactor
Fuel Composition	(Th+U233) Al	(Th+U233 / TRU)Al
Coolant Material	CO_2 / He	He
Clad Material	Mg+Al	Mg+Al
Reflector Material	Graphite	None
Core Diameter	8.6 m	2.5 m
Core Height	7.35 m	1.47 m
Power (MWth)	6.25	6.25*
Mean Inlet Gas Temperature	140 ^oC	400 ^oC
Mean Outlet Gas Temperature	336 ^oC	850 ^oC

*Power is fixed as thermal reactor due to comparison

- **Fissile Material Conditions in Thermal Reactor**

Conditions	Values
*^{233}U Enrichment (wt%)	1 / 1.5 / 2 / 3 / 4 / 5

*In this thesis, the enrichment of fissile materials has been assumed as $\frac{Fissile\ Material}{^{232}Th+Fissile\ Material}$

- **Various Conditions for Fast Reactors**

Conditions	Values
Fuel Rod Radius (cm)	1.45 / 1.20 / 1.00 / 0.80 / 0.60 / 0.35
Cladding Thickness (cm)	0.05 / 0.05/ 0.05 / 0.03 / 0.01 / 0.01
Fuel Pitch Size (cm)	20 / 15 / 10 / 9 / 8 / 7 / 6 / 5 / 4 / 3 / 2 / 1

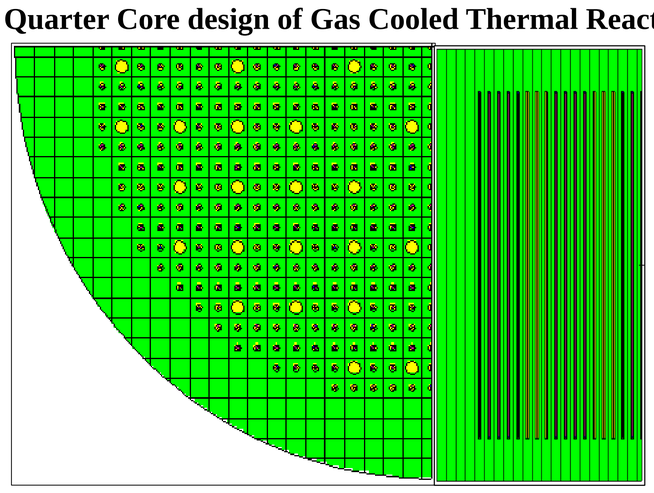
*Core diameter and height is fixed for comparison

- **TRU Compositions in Fast Reactor**

TRU Nuclides	wt%
Np-237	1.7152
Pu-238	3.0176
Pu-239	50.0963
Pu-240	31.9379
Pu-241	3.8629
Pu-242	3.1988
Am-241	3.6076
Am-242	0.2234
Am-243	1.1902
Cm-242	0.0031
Cm-243	0.0103
Cm-244	0.7526
Cm-245	0.2440
Cm-246	0.1400

3. Result

- **Quarter Core design of Gas Cooled Thermal Reactor**



- **Criticality Results with Various Fuel Compositions**

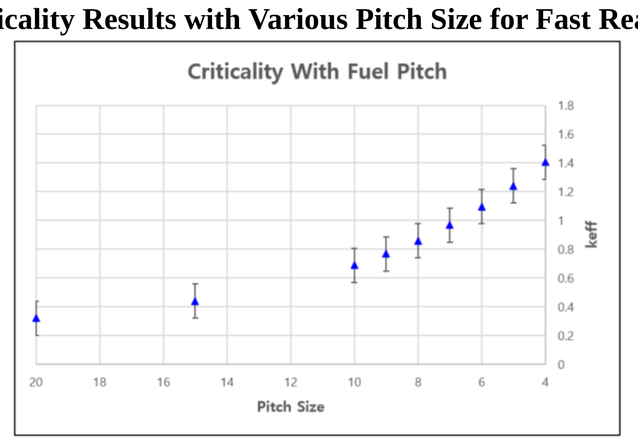
U-233 Enrichment	Criticality	std
1 wt%	0.9107	0.0056
1.5 wt%	1.1350	0.0088
2 wt%	1.2594	0.0089
3 wt%	1.4476	0.0059
4 wt%	1.5404	0.0080
5 wt%	1.6564	0.0084

- **Criticality Results with Control Rods**

Conditions	Criticality	std
1.5 wt% No Control Rod	1.1350	0.0088
1.5 wt% All Control Rods In	0.9450	0.012
2.0 wt% No Control Rod	1.2594	0.0089
2.0 wt% All Control Rods In	1.0652	0.0079

*Calculations have been performed with Thermal Reactor

- **Criticality Results with Various Pitch Size for Fast Reactor**



*Only the fuel pitch condition has been changed.

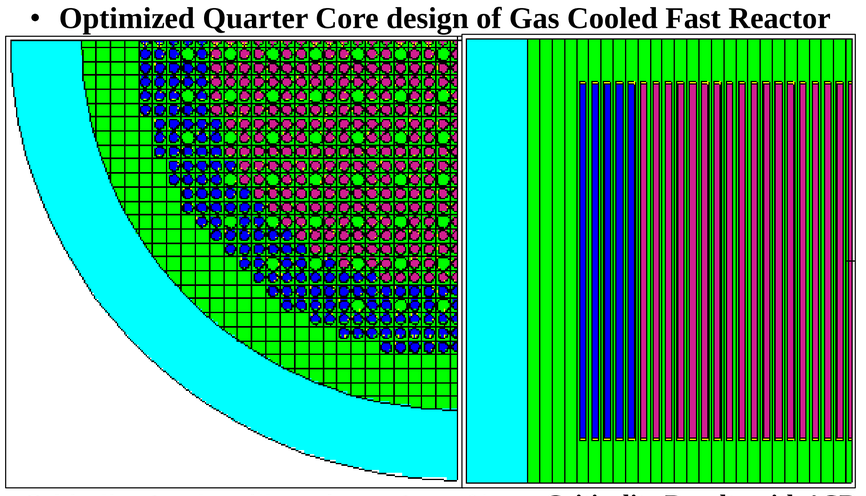
- **Criticality Results with Various Design Parameters**

Conditions			keff	std
Fuel Rod Radius (cm)	Cladding Thickness (cm)	Fuel Ptich Size (cm)		
1.45	0.05	4	1.40573	0.00075
1.20	0.05	4	1.14819	0.00058
1.00	0.05	3	1.10758	0.00059
0.80	0.03	2	1.08504	0.00067
0.60	0.01	2	0.65692	0.00046
0.35	0.01	1	0.44747	0.00031

Conditions			keff	std
Fuel Rod Radius (cm)	Core Diameter (cm)	Core Height (cm)		
1.45	172	147.198	1.14693	0.00227
1.20	172	147.198	1.03951	0.00202
1.00	129	110.3985	0.99120	0.00068
0.80	86	73.599	0.96157	0.00065
0.60	86	73.599	0.58131	0.00037
0.35	43	36.7995	0.38238	0.00031

*Calculations have been performed with Fast Reactor

- **Optimized Quarter Core design of Gas Cooled Fast Reactor**



- **Criticality Results with Various TRU wt%**

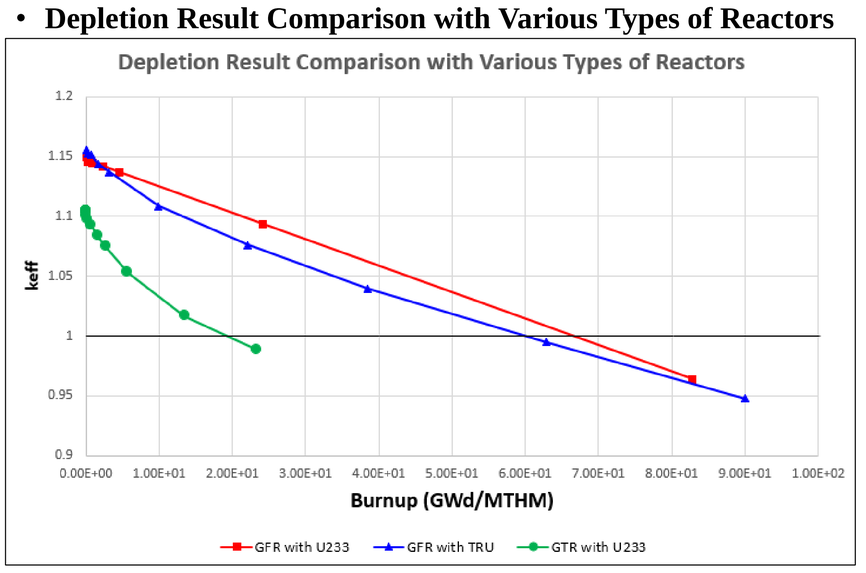
TRU wt%	keff	std
20	1.07647	0.00057
21	1.10284	0.00057
22	1.13079	0.00058
23	1.15523	0.00052
24	1.18003	0.00068
25	1.23960	0.00059

- **Criticality Results with *CR**

TRU wt%	keff	std
20	0.91655	0.00048
21	0.94852	0.00048
22	0.97969	0.00057
23	1.01117	0.00049
24	1.04166	0.00053
25	1.07131	0.00055

*CR = Control Rod

- **Depletion Result Comparison with Various Types of Reactors**



4. Conclusion

- **The gas-cooled reactors have been designed with two types, fast and thermal.**
- **The gas-cooled thermal reactor had shown burnup with about 20 GWd/MTHM which is similar to the burnup of one cycle in APR-1400.**
- **The gas-cooled fast reactor have been designed with ^{233}U and TRU isotopes for fissile materials, and the burnup had shown about 65 and 60 GWd/MTHM for ^{233}U and TRU isotopes.**
- **This thesis is the preliminary study about developing gas-cooled fast reactor with ^{232}Th, in this study it had shown the probability about design of gas-cooled fast reactor with TRU isotopes for fissile materials.**
- **In the future, it is expected to design the gas-cooled fast reactor which utilize TRU isotopes for fissile materials with ^{232}Th material.**