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BREAKEVEN CORE DESIGN STUDIES FOR A SODIUM COOLED FAST REACTOR

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ABSTRACT

The effect of the rated power on a nuclear core design has been examined for a SFR breakeven core. In order to develop the conceptual core design for a SFR, which enhances the economic potential and safety of KALIMER-600, three design core concepts were examined: 1) a zoning of a fuel fraction in a core, 2) a reduced core height to decrease the sodium void reactivity, and 3) the number of fuel zonings. It was observed that the rated power needs to be increased to at least 1,200 MWe from 600 MWe of the KALIMER-600 in order to enhance the economic potential of the fuel cycle for a commercial SFR. Even though two proposed zoning concepts, an enrichment-split and a single enrichment with varying clad thickness, have been designed to have a considerably reduced Pu fissile inventory per power and sodium void reactivity worth, the enrichment-split core concept is preferable to the single enrichment core concept from the view point of its neutron economy. For an alternative to reduce the sodium void reactivity, the concept of a reduced core height is preferable to the use of an axial moderator or absorber layer below the active core. And a zoning with two sub-regions in a core was also proposed as a core design concept. The detailed core neutronic, fuel behavior, thermal, and safety analyses will be performed for the proposed candidate core concepts to finalize the core design concept for a 1,200MWe SFR.

Key Words: breakeven core, SFR, core design, economic potential and safety

1. INTRODUCTION

According to the draft road map for a sodium cooled fast reactor (SFR) development program in Korea, the operation of a demonstrative prototype reactor will be started in 2028. For this end, a preliminary conceptual design will be developed until 2010. The rated power and the type of core, breakeven core or TRU burner, of a commercial SFR in the future have not been determined. Therefore, various design concepts for a SFR core are being developed by the Korea Atomic Energy Research Institute (KAERI) under the framework of the Gen-IV SFR development program.

This paper describes the breakeven core design studies for a SFR. The rated power of the reactor core effects the economics of a nuclear power system, and it also changes the neutronic performances of the reactor core. So, the effect of the rated power on the nuclear core design has also been examined for a SFR breakeven core. It was observed that the rated power needs to be increased to at least 1,200 MWe from 600 MWe of the KALIMER-600[1] in order to enhance the economic potential of the fuel cycle for a commercial SFR.

Three design core concepts were examined: 1) a zoning of a fuel fraction in a core, 2) a reduced core height to decrease the sodium void reactivity, and 3) the number of fuel zonings. For the zoning method, three types of core design have been investigated during the core design concept studies: 1) a core with an enrichment split fuel, 2) a core with a single-enrichment fuel with a region-wise varying clad thickness, and 3) a core with a single-enrichment fuel with non-fuel rods. The purpose of dividing the core into several sub-regions and using the concepts of an enrichment split, varying clad thickness, and non-fuel rods is to flatten the power distribution over the core by adjusting the fuel inventory for each core region. The concept of the core with a single-enrichment fuel with a region-wise varying clad thickness is one of the intrinsic features of KALIMER-600[2, 3]. The conceptual cores to establish an optimal way for a fuel zoning adopt an axial moderator or absorber layer in order to reduce the sodium void reactivity. This induces an unnecessary neutron absorption by an additional material, and the property of the core reactivity is deteriorated. Therefore, a reduction of the core height was examined in stead of using an axial moderator or absorber. And a zoning with two sub-regions in a core was also investigated to mitigate the complexity of a fuel fabrication by reducing the number of required TRU enrichment levels to two from three of the core with three sub-regions.

2. EFFECT OF THE RATED POWER ON A BREAKEVEN CORE DESIGN

For a study on the effect of the rated power on a nuclear core design, the representative cores have been developed for 600, 900, 1200, 1500, and 1800 MWe. The total number of fuel assemblies and possible arrangements of the fuel assembly loading for each rated power were determined by taking account of the desired average linear heat generation rate and the maximum power density limit, based on the performance parameters for the KALIMER-600 core [3, 4]. All the nuclear core concept design efforts were based on equilibrium cycle mode calculations. The REBUS-3 equilibrium model with a 25 group cross section was used to perform the neutronic analysis for the selected conceptual cores. Four batch reload scheme was assumed as a fuel management strategy for the conceptual cores.

Table I. Comparison of the design parameters

Design parameter	600 MWe	900 MWe	1,200 MWe	1,500 MWe	1,800 MWe
Core power(MWe)	600	900	1,200	1,500	1,800
Core height (cm)	94	90	84	80	78
Equivalent core diameter (m)	5.07	5.95	6.62	7.25	7.80
Number of fuel assemblies					
- Inner Core	114	156	198	246	300
- Middle Core	96	138	168	234	318
- Outer Core	120	162	246	300	324
- (Total)	(330)	(456)	(612)	(780)	(942)
Fuel assembly pitch (cm)	18.19	18.19	18.19	18.39	18.56
Fuel rod outer diameter (cm)	0.85	0.85	0.85	0.86	0.87
Fuel pin pitch(cm)	1.01	1.01	1.01	1.02	1.03
Pin P/D ratio	1.188	1.188	1.188	1.186	1.184

Table II. Neutronic characteristics of the conceptual cores with different rated powers

Design parameter	600 MWe	900 MWe	1,200 MWe	1,500 MWe	1,800 MWe
Burnup reactivity swing ($)	0.12	0.15	0.30	0.32	0.28
Conversion Ratio	0.999	1.001	0.999	1.001	1.005
Feed TRU wt%					
- Inner Core	12.15	12.34	12.79	12.71	12.84
- Middle Core	15.05	14.58	14.05	13.95	13.97
- Outer Core	17.94	17.49	16.56	16.20	15.99
Core average feed TRU wt%	15.10	14.81	14.65	14.43	14.30
Fissile Pu inventory (ton/GWe, BOEC)	6.02	5.26	4.96	4.86	4.88
Heavy metal loading (ton/GWe, BOEC)	60.6	53.2	49.9	49.8	50.2
Cycle length (EFPD)	540	540	540	540	540
Average linear heat generation rate (W/cm)	181	205	219	225	230
Peak linear heat generation rate (W/cm)	268	301	306	318	312
Average discharge burnup (MWD/kg)	85.0	96.4	102.6	102.8	102.2
Peak fast neutron fluence (n/cm^2)	3.97x10^{23}	4.56x10^{23}	4.86x10^{23}	4.94x10^{23}	4.96x10^{23}
Reactivity coefficient (pcm/°C, BOC/EOC)					
- Doppler coefficient at 900°K	-0.70/-0.67	-0.70/-0.67	-0.70/-0.66	-0.70/-0.66	-0.70/-0.66
- Axial expansion coefficient	-0.15/-0.14	-0.13/-0.12	-0.12/-0.11	-0.11/-0.10	-0.10/-0.10
- Radial expansion coefficient	-0.64/-0.63	-0.64/-0.63	-0.65/-0.64	-0.66/-0.65	-0.66/-0.65
- Sodium density coefficient	0.77/ 0.82	0.79/ 0.82	0.80/ 0.84	0.81/ 0.86	0.81/ 0.85
Control rod worth (pcm/rod)	442/461	267/273	226/230	150/155	141/142
Sodium void worth ($, BOC/EOC)	7.13/7.54	7.29/7.76	7.22/7.69	7.36/7.83	7.37/7.79

The main design parameters of the representative cores are listed in Table I. The core size was increased by loading more fuel assemblies with a raised power level in order to maintain the power density within the limit. However, a reduced radial leakage followed by a radial enlargement of a core induces a larger positive sodium void reactivity. Therefore, the core height for a high rated power was reduced to enhance the neutron leakage for the sodium void case. The core height was decreased from 94 cm for the 600 MWe core to 78 cm for the 1,800 MWe core. The reduced core height is effective for achieving a lower sodium void reactivity worth. The fuel outer diameter is 0.85 cm for the 600, 900, and 1,200 MWe cores. It was increased for the 1,500 and 1,800 MWe cores to maintain the conversion ratio close to 1.0. The fuel rod pitch in the 1,500 and 1,800 MWe cores was also increased in order to maintain the gap between the fuel rods. The gap between the fuel pins was for the sodium coolant flow and was designed to maintain an acceptable pressure drop along the coolant channel.

The neutronic characteristics of the conceptual core are summarized in Table II. The average required TRU enrichment of the fuel is reduced with the power level, from 15.10 wt% for a 600 MWe core to 14.30 wt% for a 1,800 MWe core. It is noted that the variation in the TRU enrichment between each region of the core is smaller with a larger core. All of the cores were designed to have a conversion ratio close to 1.0. The required fissile plutonium inventory is decreased with the core size, from 6.02 ton/GWe for a 600 MWe core to 4.58 ton/GWe for a 1,800 MWe core. The heavy metal inventory per power is also reduced as the core size increases. The higher discharge burnup, peak fast neutron fluence, and linear heat generation rate of the core with a high rated power resulted from the reduced specific fuel inventory. Comparing the fissile plutonium inventory, TRU loading, and discharge burnup, the core with a high rated power shows a more attractive aspect for its neutron economy. As shown in Fig. 1, the TRU loading per unit power is saturated at just above 1,200 MWe. The fissile plutonium loading per power shows the same trend as the TRU loading. However, the linear power density and high energy neutron fluence increase with a higher rated power. From a neutronic economical point of view, it could be suggested that the rated power of a commercial SFR be larger than 1,200MWe.

The variation in the rated power does not strongly effect the reactivity coefficients such as the Doppler, axial expansion, radial expansion, and sodium density coefficients. It should be noted that the control rod worth per control rod is remarkably reduced as the core size is increased. Therefore, as many control rods as proportional to the rated power level is required to control the reactivity of the core and to shut down the reactor.

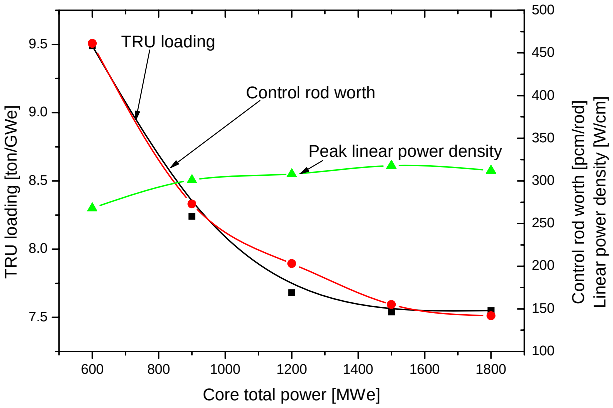

Fig.1. TRU loading, control rod worth, and linear power density variation with rated power

3. DESIGN CONCEPT STUDIES FOR A FUEL ZONING

3.1. Development of a Core Configuration

The rated power of the conceptual cores in this design concept study is assumed to be 1,200MWe. In order to explore the zoning method, three types of core designs with different fuel assemblies have been investigated during the core design concept studies: 1) a core with an enrichment split fuel, 2) a core with a single-enrichment fuel with a region-wise varying clad thickness, and 3) a core with a single-enrichment fuel with non-fuel rods.

The core under investigation was divided into three concentric regions; inner, middle, and outer core regions. The fuel assemblies loaded into each core region have different fractions of a fuel loading from each other. The purpose of dividing the core into three core regions and using the concepts of an enrichment split, varying clad thickness, and non-fuel rods is to flatten the power distribution over the core by adjusting the fuel inventory for each core region. A difference in the clad thickness with the same fuel outer diameter causes a variation in the fuel mass by changing the fuel slug volume in the fuel. The loading of non-fuel rods by replacing the fuel rods decreases the fuel volume fraction in the fuel assembly. Vacancy rod, stainless steel rod, and graphite rod were considered as a non-fuel rod[4].

Starting from the heterogeneous core configuration of the KALIMER-600 core, the number of driver fuel assemblies (leads to an increase in the radial dimension of the driver fuel region) was increased according to the raised power level to 1,200 MWe. However, a compact core design with a small number of fuel assemblies, if possible, was searched for, and a small inventory of Pu fissile of less than 6.0 ton/GWe was also searched for to enhance the fuel economy and the proliferation resistance at the same time. Possible arrangements of the fuel assembly loadings, especially that of the driver fuel assembly loadings was determined by taking into account the desired average linear power and maximum power density limit, based on the performance parameters for the KALIMER-600 core.

The basic core configurations for each core concept have been searched for by trial and error by varying the core and fuel design parameters. These basic cores satisfied almost all of the design targets. The basic cores were developed as an optimal core configuration through a sensitivity study with the core design parameters such as the fuel rod diameter, fuel rod pitch, core height, cladding thickness, and axial moderator layer thickness.

Based on the results of the sensitivity calculation of the core design parameters, the conceptual core configuration was optimized. The maximum linear heat generation rate of the core with a single-enrichment fuel with non-fuel rods was close to the design target limit and is about 15 % higher than those of the cores with an enrichment-split fuel and with a region-wise varying clad thickness fuel. An increase of the fuel inventory in the core can reduce the linear heat generation rate, but it deteriorates its economy. Therefore, two core configurations, a core with an enrichment split fuel and a core with a single-enrichment fuel with a region-wise varying clad thickness, were selected as the candidates for the conceptual core for a 1,200 MWe SFR.

3.2. Description of the Conceptual Core

The core with an enrichment-split fuel utilizes a radially heterogeneous core configuration with an annular loading of region-wise driver fuel assemblies. The total number of fuel assemblies in a core is 600: 192 FAs in the inner core, 144 FAs in the middle core, and 264 FAs in the outer core. The conceptual core has 37 control rod assemblies which are grouped into two categories: 24 control assemblies for the primary and 13 for the secondary group. The core is also composed of 96 reflector assemblies, 102 B_4C shield assemblies, 222 in-vessel storages(IVSs), and 120 radial shields. Compared with KALIMER-600, the number of fuel assemblies per unit power is reduced by 10 %.

For the configuration of the core with a single-enrichment fuel with a region-wise varying clad thickness, the total number of fuel assemblies in a core is 600, the same as that of the core with an enrichment-split fuel. The number of fuel assemblies in the inner core, middle core, and outer core are 156, 168, and 276 FAs, respectively. The numbers and loadings of the non-fuel assemblies are also the same as those of the enrichment-split core.

The main design parameters of the conceptual cores are given in Table III. The core height is reduced to 92.0 cm for both the core with an enrichment-split fuel and the core with a single-enrichment fuel with a varying clad-thickness from 94.0 cm for KALIMER-600. The reduced core height is effective for achieving a smaller sodium void reactivity worth. Each assembly includes 271 fuel pins and has a close-packed lattice. The assembly pitch is 18.22 cm for the enrichment-split fuel and 18.88 cm for the fuel with a varying clad thickness at a cold state. The fuel’s outer diameter is 0.85 cm in the enrichment-split core; however, it is increased to 0.90 cm for the fuel with a varying clad-thickness to have a conversion ratio close to 1.0. The gap between the fuel pins in the enrichment-split core is designed to be larger than that of the core with a varying clad-thickness in order to maintain an acceptable pressure drop along the coolant channel. The gap between the fuel rods is maintained with a 1.4 mm thick wire wrap. The clad thickness of the enrichment-split fuel is 0.60 mm. The various thicknesses of the clads are 0.59, 0.78, and 0.87 mm thick for the inner, middle, and outer core regions, respectively. The fuel slug outer diameter is determined to have a smear density of 75 %TD. With these design features of the fuel assemblies, the volume fractions of the fuel in the inner, middle, and outer core regions in the varying clad thickness fueled core are 27.5, 28.8, and 32.0 %, respectively. The volume fraction of the enrichment-split fuel is 30.0 %. An axial moderator below the fuel region is required to reduce the sodium void worth to within the limit. The thickness of the axial moderator layers is 15 cm for the enrichment-split core and 5 cm for the varying clad thickness core.

Table III. Comparison of the design parameters

Design Parameter	Core with Enrichment Split Fuel	Core with Varying Clad Thickness Fuel
Core Height (cm)	92.0	92.0
Number of Fuel Rods per Fuel Assembly	271	271
Fuel Assembly Pitch (cm)	18.22	18.88
Fuel Rod Outer Diameter (mm)	8.5	9.0
Fuel Slug Outer Diameter (mm)		
- IC/MC/OC	6.33/6.33/6.33	6.30/6.45/6.77
Clad Thickness (mm)		
- IC/MC/OC	0.60/0.60/0.60	0.87/0.78/0.59
Fuel Pin Pitch (cm)	1.01	1.05
Pin P/D Ratio	1.1882	1.1667
Number of Fuel Assemblies		
- IC/MC/OC	192/144/264	156/168/276
Fuel/Coolant/Structure Volume Fraction (%)		
- IC	30.0/46.0/24.0	27.5/43.1/29.4
- MC	30.0/46.0/24.0	28.8/43.5/27.7
- OC	30.0/46.0/24.0	32.0/44.6/23.4
Axial Moderator Thickness (cm)	15	5

IC, MC, and OC stand for inner core, middle core, and outer core, respectively.

3.3. Characteristics of the Conceptual Core

The major neutronic characteristics of each cores, the enrichment split core and the single enriched cores with a region-wise varying clad thickness, are summarized and compared in Table IV. The required TRU enrichment of the fuel are 13.21 wt% for the inner core, 14.13 wt% for the middle core, and 16.65 wt% for the outer core with an enrichment-split fuel; it is 14.65 wt% for the core with the varying clad thickness fuel. The average TRU enrichment of the fresh fuel assembly for the core with the enrichment-split fuel is about 14.95 wt%, which is similar to that of the core with the varying clad thickness fuel. Both cores have a conversion ratio close to 1.0. The required fissile plutonium inventories for the enrichment-split core and the varying clad thickness core are 5.32 and 5.66 ton/GWe, which satisfy the target values of less than 6.0 ton/GWe. The burnup reactivity of the core with the varying clad thickness (0.97 $) is larger than that of the enrichment-split fueled core (0.69 $). The sodium void reactivity worths of both cores are close to the target value limit of 7.5 $. The design targets for the peak fast neutron fluence, the peak linear heat generation rate, and the control rod worth are also satisfied with both conceptual core designs. Both conceptual cores satisfy all the design targets. Comparing the fissile plutonium inventory and discharge burnup, the enrichment split fueled core reveals more attractive aspects for an economic potential. However, the power distribution over the core with the burnup state reveals a large difference between the BOEC and the EOEC in Fig 2. The power distribution of the core with the single enrichment fuel does not vary much with the burnup.

The effect of the difference in the power distribution on the coolant flow distribution has been analyzed. The optimal flow groupings are shown in Figs. 3 and 4 for the enrichment split core and the single enrichment core with a varying clad thickness, respectively. The coolant flow rates are categorized into 14 groups for both the cores. The clad inner-wall temperature is lower than 650^{o}C under a normal operation during the cycle for both cores, which ensures that an eutectic melting is not expected during a normal operation. It is also noted that the power shifting between the BOC and EOC in the enrichment split core can be managed by a flow-grouping in order not to induce a eutectic melting.

Even though the core concept for a 1200MWe SFR must be finally determined by considering many aspects including its safety, fabrication cost, and fuel economy, the enrichment-split core concept is preferable to the single enrichment core concept from the view point of its neuton economy.

Table IV. Neutronic characteristics of the conceptual cores

Core Characteristics	Core with Enrichment Split Fuel	Core with Varying Clad Thickness Fuel
Burnup Reactivity Swing ($)	0.69	0.97
Conversion Ratio	0.993	1.001
TRU wt% (BOEC)		
- Inner Core	13.21	14.65
- Middle Core	14.13	14.65
- Outer Core	16.65	14.65
Fissile Pu Inventory (ton/GWe, BOEC)	5.32	5.66
Cycle Length (EFPD)	540	540
Peak Linear Heat Generation Rate (W/cm)	309	298
Average Discharge Burnup (MWD/kg)	95.5	88.8
Peak Fast Neutron Fluence (n/cm^2)	4.82×10^{23}	4.49×10^{23}
Control Rod Worth ($)	32.10	33.92
Sodium Void Worth ($)	7.49	7.44
Effective Delayed Neutron Fraction	0.00352	0.00347

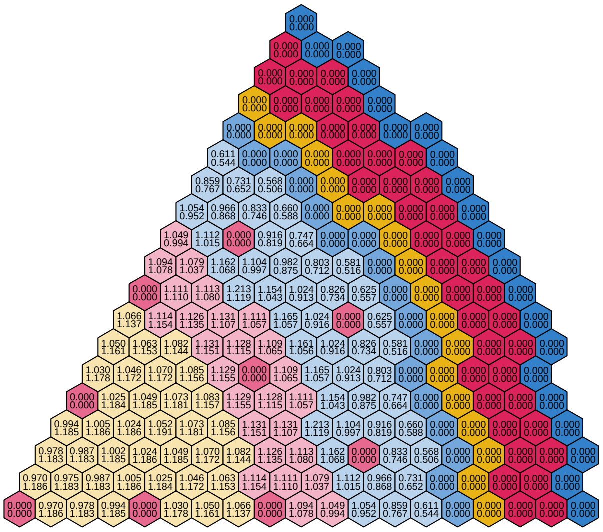

Fig. 2. Assembly-wise Power Distribution of the Enrichment-split Core

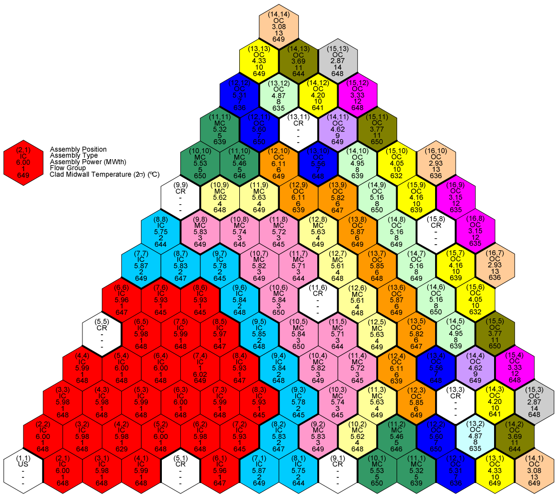

Fig. 3. Power Distributions and Flow Groups for Encirhment Split Core

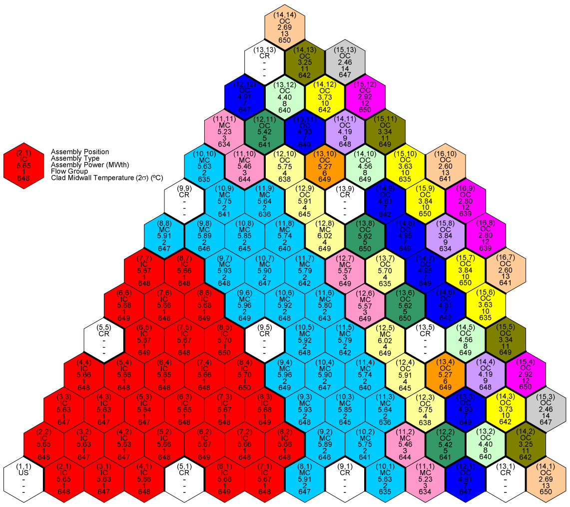

Fig. 4. Power Distributions and Flow Groups for Single Enrichment Variable Clad Thickness Core

4. ALTERNATIVE DESIGNS TO THE CONCEPTUAL CORE

4.1. Development of a Core with a Reduced Height

It was observed that a larger core size following the increased rated power improves the fuel economy. A large core, however, has an increased positive sodium void reactivity due to the reduced neutron leakage effect when a sodium void occurs. In order to reduce the sodium void reactivity, the use of an additional moderating material[5] in a neighboring region, just below the active core, to the effective core has been examined. The moderator or absorber materials that are under investigation are BeO, graphite, stainless steel, sodium, and B_4C. After adding a 15cm-thick axial layer of these materials to below the active core, its effect on the sodium void reactivity was evaluated. The use of graphite, stainless steel, and sodium do not have an effect on the sodium reactivity significantly. The sodium void reactivity was reduced by 0.5$ with BeO and 1.5$ with B_4C, respectively. However, since BeO and B_4C deteriorate the core reactivity, an increased TRU loading is required to maintain the cycle length.

An alternative way to decrease the sodium void reactivity is to reduce the core height. The core height was reduced to 80cm to satisfy the design target for the sodium void reactivity; the core height of the original configuration with a B_4C axial layer was 92cm. The decreased fuel inventory caused by the reduced core height did not achieve a conversion ratio of ~1.0. Therefore, the number of fuel assemblies and the fuel rod diameter were increased to maintain the breakeven capability. The core configuration with a reduced height is shown in Fig. 5. The main design parameters and neutronic characteristics of the reduced height core are given in Tables V and VI.

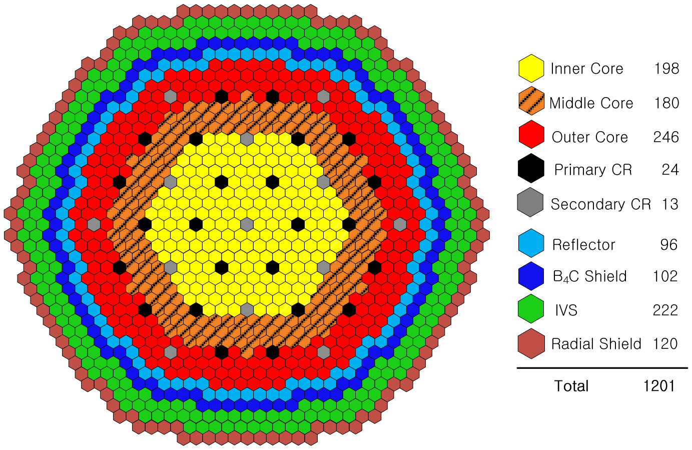

Fig. 5. Configuration of the Core with a Reduced Height

Table V. Comparison of the design parameters

Design Parameter	Reduced height core design	Two sub-regions core design
Core Height (cm)	80.0	80.0
Fuel Assembly Pitch (cm)	18.45	18.45
Fuel Rod Outer Diameter (mm)	8.7	8.7
Fuel Slug Outer Diameter (mm)	6.50	6.50
Clad Thickness (mm) - IC/MC/OC	0.60	0.60
Fuel Pin Pitch (cm)	1.03	1.03
Pin P/D Ratio	1.184	1.184
Number of Fuel Assemblies - IC/MC/OC	198/180/246	318/-/306

Table VI. Neutronic characteristics of the alternative cores

Core Characteristics	Reduced height core design	Two sub-regions core design
Burnup Reactivity Swing ($)	0.64	0.63
Conversion Ratio	0.993	0.993
TRU wt% (BOEC)		
- Inner Core	13.05	13.16
- Middle Core	14.33	-
- Outer Core	16.90	16.79
Core average feed TRU wt%	14.94	14.94
Fissile Pu Inventory (ton/GWe, BOEC)	5.06	5.06
Cycle Length (EFPD)	540	540
Peak Linear Heat Generation Rate (W/cm)	319	320
Average Discharge Burnup (MWD/kg)	100.1	100.1
Sodium Void Worth ($)	7.26	7.25
Peak Fast Neutron Fluence (n/cm^2)	$4.74x10^{23}$	$4.72x10^{23}$
Effective Delayed Neutron Fraction	0.00353	0.00353

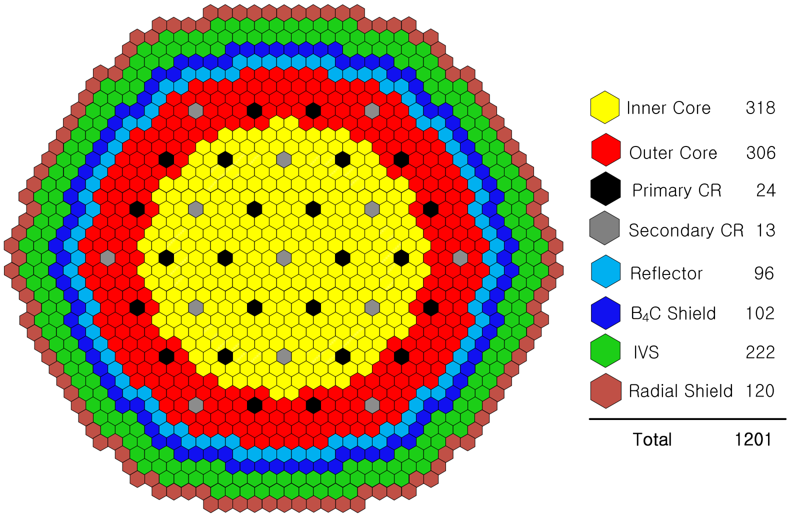

Fig. 6. Configuration of the Core with a Reduced Height and Two Sub-regions

4.2. Development of a Core with Two Sub-regions

The purpose of dividing the core into several sub-regions is to have a more flattened power distribution over the core by adjusting the fuel inventory for each core region. Generally, the more sub-regions the core is divided into, the easier the power distribution control is. However, many of the sub-regions in a core require as many kinds of fuel assemblies as the sub-regions, which makes a fuel fabrication complicated. Therefore, it is preferable to control the core power distribution by a fuel zoning with a lesser number of sub-regions.

The zoning with two sub-regions in a core was investigated in stead of the three sub-regions concept which was used in previous core designs. Fig. 6 shows the core configuration with two sub-regions. As shown in Tables V and VI, the design parameters and core neutronic characteristics of the two sub-region core are not much different from those of the core with three sub-regions. The power distribution for the three sub-regions core in Fig.7 shows a rather smooth transition within 7% of a discrepancy along the region interfaces. Even though a steep increase of ~15% in power across the interface between inner core and outer core was occurred in two sub-region case as shown in Fig. 8, it is noted that the maximum linear power of this core is close to that of three sub-region core. The grouping of the coolant flow would be expected to maintain the thermal performance of the core within the operable ranges.

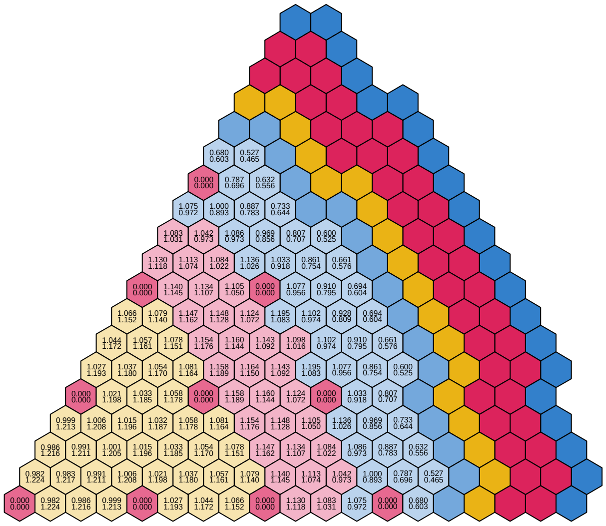

Fig. 7. Assembly-wise Power Distribution with Three Sub-region Core

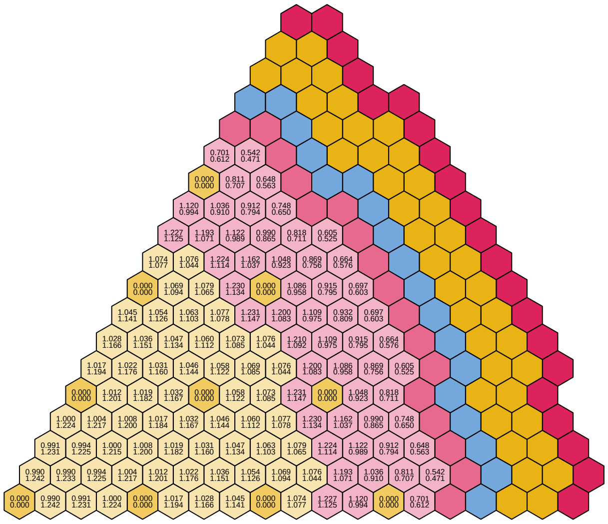

Fig. 8. Assembly-wise Power Distribution with Two Sub-region Core

5. CONCLUSIONS

The effect of the rated power on the nuclear core design has been examined for a SFR breakeven core. It was observed that the rated power needs to be increased to at least 1,200 MWe from 600 MWe of the KALIMER-600[1] in order to enhance the economic potential of the fuel cycle for a commercial SFR.

In order to develop a conceptual core design for a 1,200 MWe SFR, which enhances the economic potential and safety of KALIMER-600, three design core concepts were examined: 1) a zoning of a fuel fraction in a core, 2) a reduced core height to decrease the sodium void reactivity, and 3) the number of fuel zonings.

Two fuel zoning concepts, sub-regions with an enrichment-split fuel and sub-regions with a single-enrichment fuel with a region-wise varying clad thickness, have been proposed as the design concepts for the SFR core. Compared with KALIMER-600, the two proposed cores have been designed to have a considerably reduced Pu fissile inventory per power and sodium void reactivity worth. Even though the core concept for a 1200MWe SFR must be finally determined by considering many aspects including its safety, fabrication cost, and fuel economy, the enrichment-split core concept is preferable to the single enrichment core concept from the view point of its neutron economy.

For an alternative to reduce the sodium void reactivity, the concept of a reduced core height is preferable to the use of an axial moderator or an absorber layer below the active core. And a zoning with two sub-regions in a core was also proposed as a core design concept.

The detailed core neutronic, fuel behavior, thermal, and safety analyses will be performed for the proposed candidate core concepts to finalize the core design concept for a 1,200MWe SFR.

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