CHAPTER 6

FUTURE CORE CONFIGURATIONS

6.1 Overview of Refueling Strategy

The fuel replacement strategy for Core No's 6-12 that was studied in this method is quite simple. Considerable shuffling was done with the partially-burned 8.5 wt.% U elements currently in Core No 5. After investigated the fuel burnup at the end of Core No 5, the average burnup were 6.86 % for ring B, 8.16 % for ring C, 2.25 % for ring D (contain 14 elements with 20 wt.% LEU) 9.80 % for ring E, 7.03 % for ring F and 7.09 % for ring G. Thus, from these results the basic strategy is to keep the 20 wt % U elements in the D-ring in Core No.5 in their current positions, move the partially-burned 8.5 wt % U elements with the highest ^{235}U loadings into the B-and C-rings of successive cores and insert fresh elements with 20 wt % U first into the E-ring and then into the F-ring. Seven fresh elements were replaced per refuelling in the 21-standard-element E-ring and ten elements were replaced per refueling in the 30-standard-element F-ring. For G-ring, refueling should be performed after this.

6.2 Core No.6

Before inserting new fresh elements with 20 wt % U into the core, it was thought to be prudent to obtain the maximum burnup from the existing partially-burned elements with 8.5 wt.% U. As a test, the five (except Thermocouple in B) 8.5 wt.% U elements with the highest

^{235}U content at EOC in Core No. 5 were moved into the B-ring and the eleven 8.5 wt % U elements with the next highest ^{235}U content were moved into the C-ring by interchanging the fuel elements with the G-and F-rings as shown in table 6.1 . Elements were also shuffled in the E-, F-, and G-ring using the same principle as shown in table 6.2 No fresh elements with 20 wt % U were added. The complete loading list is shown in Appendix F .

A burnup calculation showed that (see Appendix E) this core could be operated for 64.4 MWd with an EOC excess reactivity of 1.9 % $\delta k/k$, which represents the same radioisotope sample load as Core No. 4.

Since 64.4 MWd is a significant energy release, which could allow the core to operate for more than one year, the above loading for Core No.6 was accepted as a possible core in the sequence that was studied. More detailed data on the ^{235}U loading, power densities, and reactivity burnup history of Core No. 6 is provided in Appendix E.

Core No. 6 has the same peak power density in all of cores that were studied. This power peak was calculated to be 58.78 W/cm^3 in position D6 and is only slightly larger than the peak value (also in position D6) of 58.62 W/cm^3 in Core No.5. The reason is that the total power in the B-and C-ring is slightly larger in Core No.6 due to the fuel shuffle and burnup of the D-ring elements in Core No.5.

Table 6.1 Fuel rearrangement for Core No.6 (part 1)

Fuel element No.	Core No. 5 EOC U-235 mass; g	Positions	Interchange with	Fuel element No.	Core No. 5 EOC U-235 mass, g	Positions
8571	33.636	B2		8615	35.814	G9
8589	33.509	B3		8636	36.097	G30
8574	33.395	B4		8625	35.812	G3
8640	33.526	B5		8618	35.783	G11
8630	33.624	B6		8600	35.738	G35
8628	33.553	C1		8616	35.735	G10
8596	33.603	C2		8639	35.677	G29
8595	33.748	C3		8601	35.633	G4
8607	33.339	C5		8642	35.597	G27
8563	32.939	C6		8620	35.564	G34
8622	33.122	C7		8627	35.364	G17
8650	33.431	C8		8643	35.546	G16
8649	33.713	C9		8560	35.523	G21
8621	33.573	C10		8578	35.488	F6
8624	33.473	C11		8610	35.485	G22
8611	33.080	C12		8606	35.435	F26

Table 6.2 Fuel rearrangement for Core No. 6 (part 2)

Fuel element No.	Core No. 5 EOC U-235 mass, g	Positions	Interchange with	Fuel element No.	Core No. 5 EOC U-235 mass, g	Positions
8631	33.278	E1		8613	35.288	F1
8597	33.443	E2		8566	35.002	F2
8623	33.421	E3		8585	34.876	F3
8632	33.188	E4		8588	34.752	F4
8568	33.333	E5		8648	34.943	F5
8584	32.409	E7		8626	34.903	F10
8561	33.847	E10		8593	35.361	F11
8635	32.961	E12		8646	34.852	F12
8605	33.006	E13		8587	34.761	F15
8575	33.504	E14		8586	35.093	F16
8608	32.938	E16		8637	34.730	F17
8572	33.128	E17		8638	34.728	F20
8612	33.523	E18		8558	35.265	F21
8565	33.677	E23		8647	34.971	F22
8602	33.609	E20		8579	35.129	F25
8573	33.430	E21		8614	34.755	F27
8559	33.777	E22		8577	34.805	F29
8645	33.717	E24		8644	34.918	F30
8594	33.230	E9		8634	35.314	G12
8562	33.565	E11		8582	34.984	G15
8564	33.151	E15		8591	34.902	G23
8583	32.566	F18		8581	34.478	G24

6.3 Core No.'s 7-9

At the end of core No 6, carefully examined was done throughout the core. It was found that ^{235}U content in the fuel elements in B-and C-rings were still higher than that of the outer rings (rings beyond D-ring). In this case it had to discharge from the core some 8.5 wt.% fuel elements with lowest ^{235}U content in order to insert fresh elements with 20 wt % U into the core. Thus, core No.7 was constructed by :

1) Discharging seven partially-burned 8.5 wt.% U with lowest ^{235}U content, mostly in F-ring and a few in G-ring.

2) Moving seven elements from E-ring into the vacated positions.

3) Inserting (symmetrically) seven fresh elements with 20 wt % into the vacated positions in E-ring.

See table 6.3 for fuel manipulation steps. The energy release of 95.0 MWd was predicted, with seven fresh 20 wt % U elements inserted into E-ring for core No.7 and for an EOC excess reactivity of 1.9 % $\delta k/k$. (based on EOC excess reactivity in core No.4).

For rearranging the fuel and refueling procedures of core No 8-9, the procedure for Core No.7 was repeated, with seven fresh 20 wt % U elements inserted into the E-ring in successive cores. (see table 6.3)

6.4 Core No.'s 10-12

The above procedure was repeated, with ten fresh 20 wt % U elements inserted into the F-ring at each refueling (see table 6.4

for coresponding core.) A loading list is provided in Appendix F.

Table 6.3 Fuel Manipulation Steps

(a) Core No. 7

New 20 wt % U	E-23	G-34	discharged
New 20 wt % U	E-15	G-24	discharged
New 20 wt % U	E-11	F-12	discharged
New 20 wt % U	E-3	F-17	discharged
New 20 wt % U	E-21	F-15	discharged
New 20 wt % U	E-17	F-10	discharged
New 20 wt % U	E-7	F-9	discharged

(b) Core No. 8

New 20 wt % U	E-1	F-4	discharged
New 20 wt % U	E-13	G-17	discharged
New 20 wt % U	E-5	F-5	discharged
New 20 wt % U	E-9	G-26	discharged
New 20 wt % U	E-20	F-26	discharged
New 20 wt % U	E-18	F-20	discharged
New 20 wt % U	E-10	G-23	discharged

(c) Core No. 9

New 20 wt % U	E-2	F-2	discharged
New 20 wt % U	E-24	F-1	discharged
New 20 wt % U	E-22	F-27	discharged
New 20 wt % U	E-4	F-3	discharged
New 20 wt % U	E-16	G-27	discharged
New 20 wt % U	E-12	G-16	discharged
New 20 wt % U	E-14	G-12	discharged

Table 6.4 Fuel Manipulation Steps

Core No. 10

New 20 wt % U	→	F-15	→	C-7	→	discharged
New 20 wt % U	→	F-17	→	C-8	→	discharged
New 20 wt % U	→	F-12	→	C-6	→	discharged
New 20 wt % U	→	F-20	→	B-4	→	discharged
New 20 wt % U	→	F-9	→	B-3	→	discharged
New 20 wt % U	→	F-7	→	B-2	→	discharged
New 20 wt % U	→	F-4	→	C-12	→	discharged
New 20 wt % U	→	F-2	→	B-6	→	discharged
New 20 wt % U	→	F-28	→	B-5	→	discharged
New 20 wt % U	→	F-26	→	C-10	→	discharged

Core No. 11

New 20 wt % U	→	F-21	→	discharged		
New 20 wt % U	→	F-22	→	discharged		
New 20 wt % U	→	F-29	→	discharged		
New 20 wt % U	→	F-30	→	discharged		
New 20 wt % U	→	F-16	→	discharged		
New 20 wt % U	→	F-3	→	C-1	→	discharged
New 20 wt % U	→	F-5	→	C-2	→	discharged
New 20 wt % U	→	F-11	→	C-5	→	discharged
New 20 wt % U	→	F-13	→	C-11	→	discharged
New 20 wt % U	→	F-19	→	C-9	→	discharged

Core No. 12

New 20 wt % U	→	F-6	→	C-3	→	discharged
New 20 wt % U	→	F-1	→	discharged		
New 20 wt % U	→	F-8	→	discharged		
New 20 wt % U	→	F-10	→	discharged		
New 20 wt % U	→	F-14	→	discharged		
New 20 wt % U	→	F-18	→	discharged		
New 20 Wt % U	→	F-23	→	discharged		
New 20 wt % U	→	F-24	→	discharged		
New 20 wt % U	→	F-25	→	discharged		
New 20 wt % U	→	F-27	→	discharged		

6.5 Summary of Results

A summary of the calculated results for Cores 5-12 is shown in Table 6.5 Detailed information showing the ^{235}U loadings, power densities, and burnup histories are provided in Appendix E.

Table 6.5 Summary of Calculated Data for Core No.'s 5-12

Core No.	Total MWd	Excess React., % δk/k,($) BOC	EOC	BOC Peak Power Density in Homogenized Cell* W/cm^3	^{235}U Content, g	Exquilibrium Xenon, $
5	150.85	4.875($6.69)	1.907($2.72)	58.62	99.67	2.36
6	64.40	4.119($5.87)	1.906($2.72)	58.78	96.58	2.34
7	95.00	4.297($6.14)	1.904($2.72)	57.59	95.25	2.29
8	99.33	4.222($6.03)	1.918($2.74)	56.56	93.43	2.20
9	93.39	4.053($5.79)	1.905($2.72)	55.23	91.55	2.14
10	149.5	4.291($6.13)	1.908($2.73)	54.08	89.83	2.03
11	122.9	4.002($5.72)	1.890($2.70)	52.28	87.14	1.97
12	116.5	4.132($5.90)	1.903($2.72)	50.62	84.99	2.23

Total 891.87

* The peak power density occurs at D6 in all cores.

6.6 Simplification of refueling scheme

In order to use the schemes more effectively it is possible to simplify the refueling scheme. The technique was devised, by inserting the seven new 20 wt % LEU elements into the E-ring at the end of Core No. 6 followed by burnup calculation. Recalculate again by inserting fourteen new 20 wt % LEU elements and again with twenty one new 20 wt.% LEU elements.

For F-ring, above procedures were repeated by inserting ten, twenty and thirty new 20 wt.% LEU elements into F-ring followed by successive calculations. The results of these calculations are shown in Fig 6.1 and table 6.6

Table 6.6 Calculated data for refueling in E-and F-rings

E-ring refueling		F-ring refueling	
No. of new 20 wt.% LEU	MWd	No. of new 20 wt.% LEU	MWd
7	95.0	10	149.5
14	198.9	20	261.6
21	295.1	30	382.5

From Fig 6.1 it shows that the number of MWd varies linearly to the number of elements loaded in E- or F-ring. Thus, expected MWd's can be estimated with a given number of new fuel elements by using the correlation shown in Fig. 6.1. This provides a convenient mean to determine approximate life of a core loading. Thus , any number of the new fuel elements can be inserted for the designed MWd of operation can be achieved. This makes the schemes adjustable with no adversely affected to the result. It should be noted that these graphs cannot be used simultaneously, only one can be used each time.

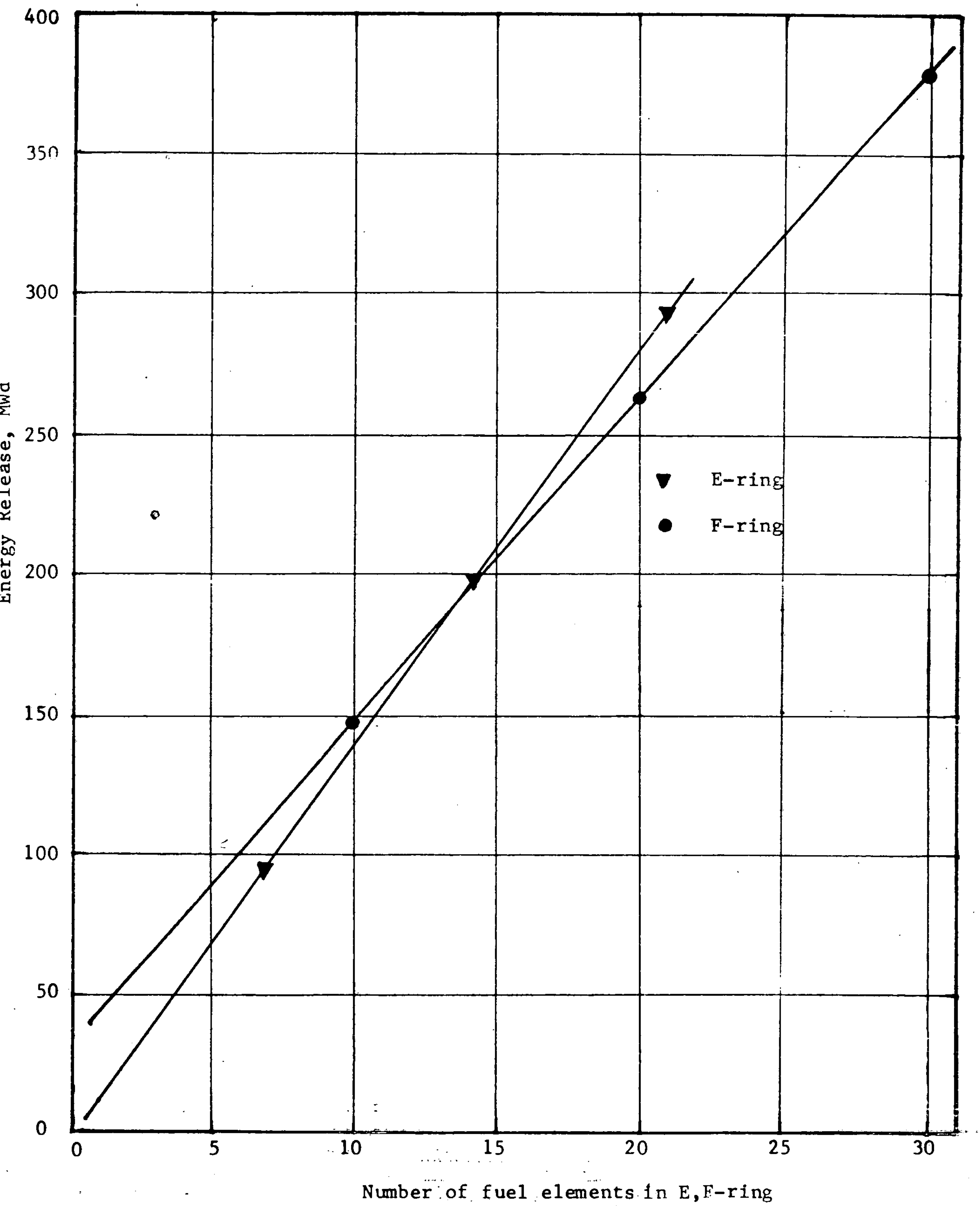

Fig. 6.1 Energy Release VS Number of Fresh Fuel Elements loaded in E,F rings