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Analysis of CANDU-6 Transition Core Refuelled from 37-Element Fuel to CANFLEX-NU Fuel

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Abstract

The CANDU-6 transition core refuelled from 37-element fuel to CANFLEX-NU fuel has been evaluated by an 100 full power day time-dependent fuel-management simulation to find the core compatibility with the CANFLEX fuel loading. The simulation calculations for the transition core were carried out with the RFSP code, provided by the cell averaged fuel properties obtained from the POWDERPUFS-V code. The simulation results were compared with those of the current 37-element fuel loading only. The results show that the CANFLEX-NU fuel bundles will be compatible with the CANDU-6 reactor because the core physics characteristics of CANFLEX-NU fuel are very similar to those of the 37-element fuel bundle.

I. Introduction

The CANFLEX(CANDU FLEXible fuelling) fuel has been developed jointly by KAERI and AECL[1]. The CANFLEX fuel bundle has 43 fuel elements. There are two element size with small diameter elements in the outer two rings and large diameter elements in the inner ring and the centre.

This paper presents the physics characteristics of the transition core refuelled from 37-element fuel to CANFLEX-NU fuel in the CANDU 6 reactor. The calculation results will be compared to those of the 37-element fuel loading only.

II. Methodology

II.1 Reactor Model

Calculations were performed using 3-dimensional full core model as shown in Figure 1. Figure 2 shows the CANFLEX fuel cell model.

The transition simulation was performed using the fuel-management code RFSP[2], provided by the cell averaged fuel properties obtained from the POWDERPUFS-V code[3].

II.2 Modelling the Transition Core

The time-dependent refuelling simulation was performed with using 10-full-power-day refuelling intervals for 100 Full Power Days(FPD's). The starting point was an instantaneous time of the equilibrium core fully loaded with 37-element fuel bundles only.

In the transition period, refuelling took place with the CANFLEX-NU fuel bundles only, using a regular 8-bundle shift fuelling scheme. Also, 37-element fuel bundle fuelling simulation was also performed with the same fuelling sequence. in order to compare the physics characteristics between them.

III. Results and Discussion

III.1 Global Power Distribution

Figures 3 and 4 show the time-average channel and bundle power profiles for the equilibrium 37-element and CANFLEX-NU partially fuelled cores.

The peak channel and bundle powers for the model with time-averaged fuel properties are 6.64 MW and 804 kW, respectively. The margins between the peak powers and the target instantaneous operating limits of 7.30 MW for the channel power and 935 kW for the bundle power are judged to be sufficient to cover the refuelling ripple (in a 8-bundle shift scheme) plus power prediction uncertainties. The average equilibrium exit fuel burnup is calculated as 7140 MWd/MgU or 171 MWh/kgU.

III.2 Power Distribution During Transition Period

The power distribution during the transition period were calculated for 100 FPD, refuelling of 43-CANFLEX fuel bundles in the equilibrium core fully loaded with 37-element fuel bundles. The channel and bundle power distributions by the 100 FPDs transition simulation were then compared with the those obtained by 37-element bundle refuelling simulation calculations with the same refuelling sequence.

Figures 5 shows the full core maps of channel power differences between the transition core refuelled from 37-element to CANFLEX fuel and the equivalent core refuelled with the same 37-element bundles at 100 FPDs.

Figure 6 show a comparison between the peak channel powers of the transition simulation core and the core refuelled with the 37-element bundles only by the same refuelling sequence. The CANFLEX-NU fuel bundle shows slightly higher maximum channel powers in the transition core, compared with the normal core refuelled with the 37-element bundles only. Peak bundle powers are also compared in Figure 7, in which peak bundle powers in the transition core are slightly higher than those from the normal core.

These variations of channel and bundle power distributions in the during the transition core refuelled from the 37-element fuel to the CANFLEX fuel are less than 1 % and also are within the range of the design limit.

IV. Summary

The CANDU-6 transition core refuelled from 37-element fuel to CANFLEX-NU fuel has been evaluated by a 10-day refuelling intervals in an 100 full power day time-dependent fuel-management simulation to find the core compatibility with the CANFLEX fuel loading.

The calculated transition-core characteristics were compared with those of the core refuelled with 37-element fuel only. According to the calculated results, the global power distributions of the transition core are almost identical to those of the 37-element fuelled core. It is also shown that variations of the channel and bundle powers of the transition core are less than 1%. Therefore. it can be concluded that the CANFLEX-NU fuel is compatible with current CANDU 6 reactor during the transition period.

References

1. H.C. Suk et al., "Development of the Advanced CANDU Technology", KAERI Report KAERI/RR-1229/92 (1993).
2. D.A. Jenkins and B. Rouben, "Reactor Fuelling Simulation Program - RFSP :User's Manual for Microcomputer Version" AECL Report TTR-321 (1993).
3. D.B. Miller and E.S.Y. Tin, "POWDERPUFS-V User's Manual", AECL CANDU Report TDAI-31 part 2 of 3 (1976).

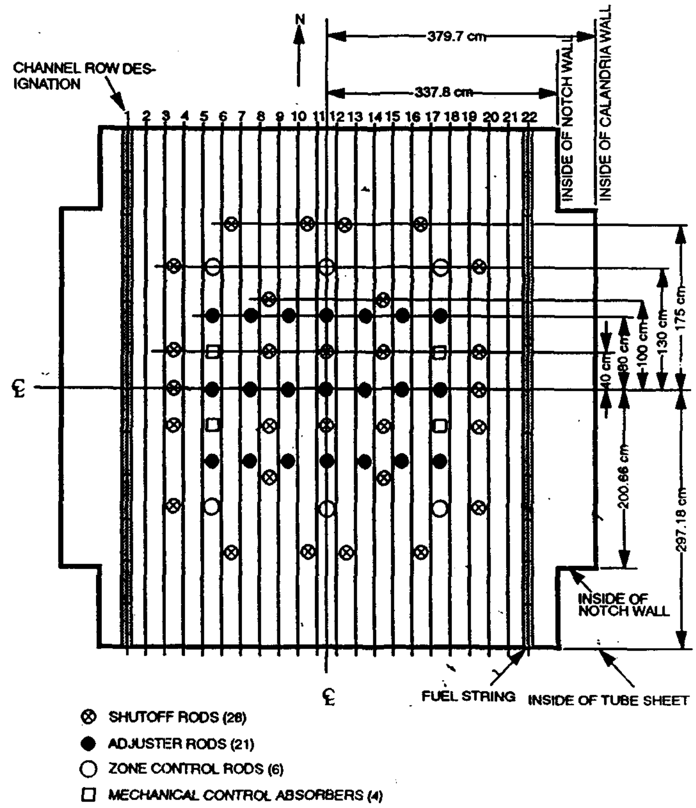

Figure 1 Plan View of Reactor Showing Pricipal Calandria Dimension and Layout of Reactivity Devices

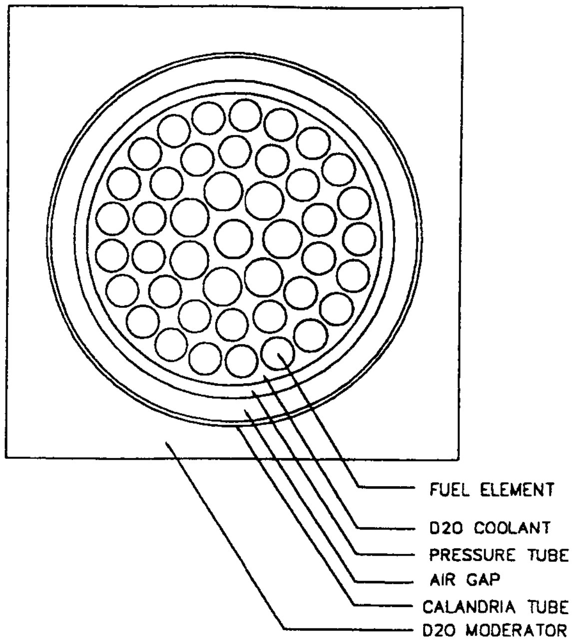

Figure 2 Lattice Cell for CANFLEX Fuel

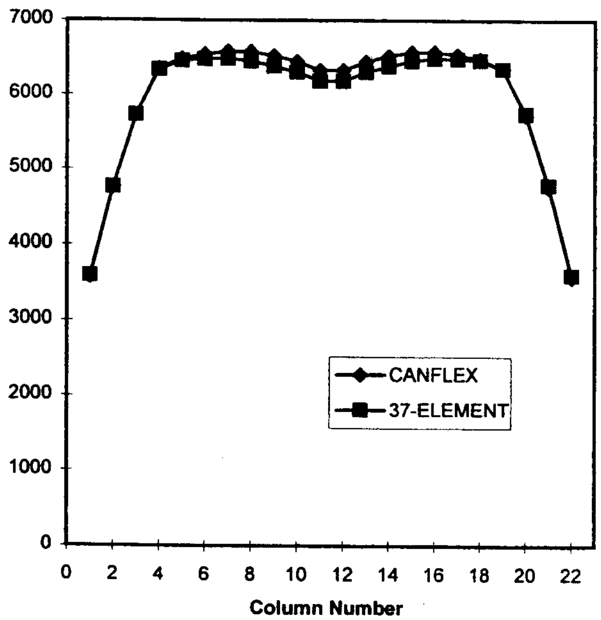

Figure 3 Time-Averaged Channel Powers (Row L)

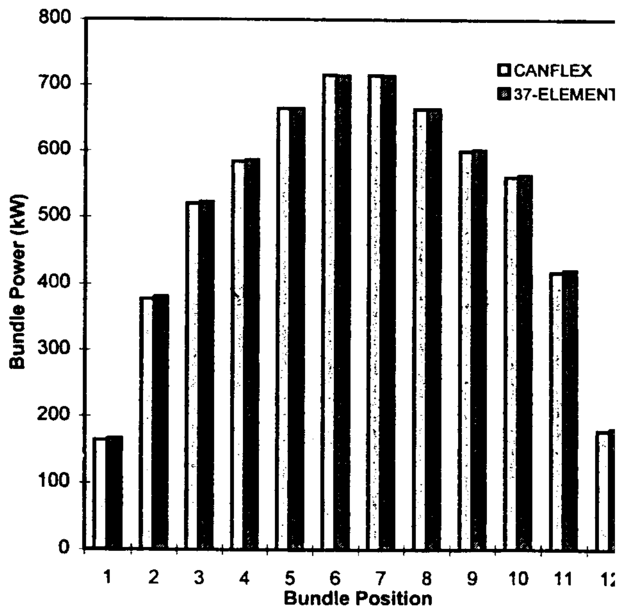

Figure 4 Time-Averaged Axial Bundle Power (Channel L-11)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A									0.3	0.7	0.4	0.3	0.3	0.4								
B						0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.6	0.4	0.4	0.4					
C					0.2	0.6	0.2	0.2	0.2	0.3	0.8	0.3	0.3	0.3	0.3	0.7	0.4	0.3				
D				0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3			
E			0.5	0.2	0.2	0.1	-0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4		
F			0.1	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.6	0.3	0.3	0.7		
G		0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	
H		-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.7	
J	-0.0	-0.0	-0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.0	-0.0	-0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3
K	-0.1	-0.0	0.3	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.0	-0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.2
L	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.0	-0.0	-0.0	0.0	0.1	0.1	0.6	0.2	0.2
M	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	0.2	-0.1	-0.1	-0.1	-0.1	0.2	-0.0	-0.0	-0.0	0.0	0.1	0.2	0.2	0.2
N	0.3	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.0	0.1	0.1	0.6	0.2
O	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.0	0.0	0.1	0.2	0.2
P		-0.1	0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.0	0.0	0.1	0.1	
Q		-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.3	-0.2	0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1	0.0	0.5	0.1	
R			-0.2	0.1	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	-0.1	-0.0	0.1		
S			-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	0.2	-0.1	-0.1	-0.0	0.0		
T				-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	-0.1	-0.0			
U					-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.1	0.3				
V						-0.3	-0.3	-0.3	-0.3	0.1	-0.2	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1					
W									-0.3	-0.2	-0.2	-0.2	-0.2	0.1								

Maximum Difference in Channel Power : 0.71 %
Maximum Difference in Bundle Power : 0.91 %

$$\text{Percent Difference} = \frac{(\text{43-CANFLEX transition}) - (\text{37-element only})}{(\text{37-element only})} \times 100\ (\%)$$

Figure 5 Channel Power Difference after 100-FPD Transition

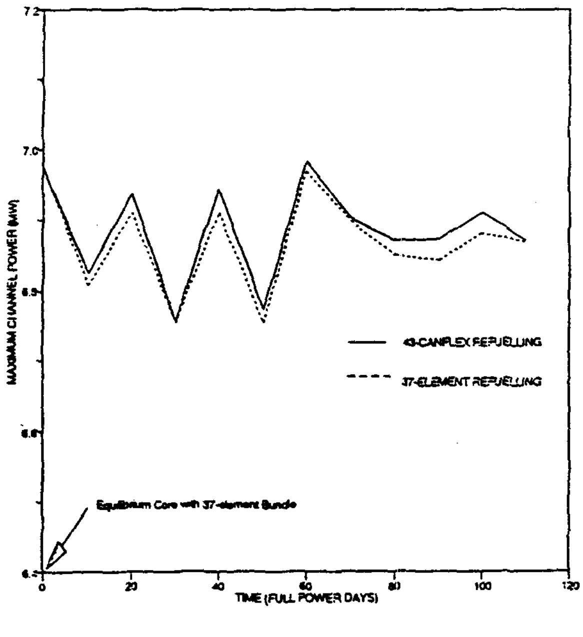

Figure 6 Maximum Channel Power vs. Time after Transition

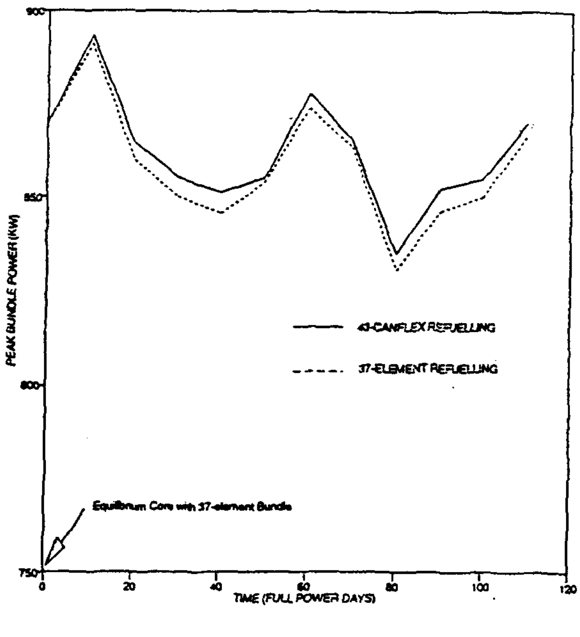

Figure 7 Maximum Bundle Power vs. Time after Transition