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Fuel Management Simulation for CANFLEX-RU in CANDU 6

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Abstract

Fuel management simulations have been performed for CANFLEX-0.9% RU fuel in the CANDU 6 reactor. In this study, the bi-directional 4-bundle shift fuelling scheme was assumed. The lattice cell and time-average calculation were carried out. The refuelling simulation calculations were performed for 600 full power days. Time-averaged results show good axial power profile with the CANFLEX-RU fuel. During the simulation period, the maximum channel and bundle power were maintained below the licensing limit of CANDU 6 reactor.

1. Introduction

The CANFLEX fuel bundle, developed to provide additional flexibility for the design and operation of CANDU reactors, has the extended burnup capability and enhanced operating margins necessary for the use of advanced fuel cycles in existing CANDU reactors[1-3]. These advanced, economical fuel cycles are characterized by fuel with a higher fissile contents than is the enrichment of natural uranium(NU). The 1.2% slightly enriched uranium(SEU) is calculated to be the optimum enrichment with uranium savings of 30-39%[4], while the 0.9% SEU which has 23-31% of uranium savings is also economically attractive with no technical difficulties anticipated compared to 1.2% SEU[3]. Furthermore, the recovered uranium(RU) from LWR fuel has an enrichment of around 0.9% U-235 in total uranium and is a potentially cheaper alternative to 1.2% SEU in CANDU reactors when strategic considerations are favourable.

This paper represents the 600 FPD(Full Power Day) refueling simulation results of the CANFLEX-RU fuel in the CANDU 6 reactor.

2. Calculation Procedure

2.1 Reactor Model

The CANDU 6 reactor- has 380 fuel channels. Flux and powers are calculated in 3-dimensions using 44 x 36 x 24 mesh points in the x-, y- and z-directions respectively. The calculations were performed using the reactor simulation code RFSP[5] which performs the 3-dimensional flux and power distribution calculations for the core by solving the finite-difference neutron diffusion equations in two groups.

2.2 Lattice Calculation

The lattice cell code WIMS-AECL[6] and ENDF-V library were used to generate fuel properties. The transport calculation in the WIMS-AECL was done in 33 energy groups. The cell-averaged cross sections were processed by WIMCORE[7] code.

2.3 Time-average Model

In the time-average calculation, properties of lattice cell are averaged over the fuel dwell time in the core. In setting up the time-average model, the core is divided into 5 irradiation zones, over which the average discharge irradiation is constant. The fuelling scheme was chosen to bi-directional 4 bundle shift. The water level of the zone control compartments were set to 50% full, representative of the normal operating conditions.

2.4 Instantaneous Core Model

The instantaneous calculation provides a "snapshot" of the core power and burnup distribution at some point in time. Every channel in the core is assigned an age which indicates the fraction of dwell-time between visit of a fuelling machine to the channel. In this calculation, the patterned random channel age[4] was used.

2.5 Time-dependent Fuelling Simulation

In order to estimate parameters such as the peak power and refueling ripple, a time-dependent refueling simulation was performed for 600 full power days. The starting point was an instantaneous model. For the bulk and spatial control of the reactor power, the action of the zone controllers were allowed. In this calculation, 4-bundle shift refueling scheme was chosen. The refueling simulations were performed under the condition that the rippled bundle and channel power should be lower than limiting condition of the CANDU 6 reactor.

3. Results and Discussion

3.1 Time-Average Calculation

Time-averaged radial channel power distribution is shown in Figure 1 for a row channels along the horizontal mid-plane. It is evident from the result that the adjuster rods flatten the radial power distribution. Figure 2 illustrates time-averaged power profile in the axial direction for a central channel. The adjuster rods do not cause a significant depression in the power over the centre of the channel.

3.2 Time-dependent Fuelling Simulation

The results of the instantaneous power calculation were used in the time dependent simulation as a starting point. The variation of maximum channel power is presented in Figure 3. It can be seen that the maximum channel powers are maintained below limit value(7300 kW) during 600 full power days. The maximum bundle power profiles are shown in Figure 4. The maximum bundle powers are also well below the operating limit(935 kW).

4. Summary

Fuel management study for CANFLEX-0.9% RU fuel in the CANDU 6 reactor was performed. Lattice calculations preceeded the core calculations ; they provided cell average fuel properties for core calculations. Time-average calculation give an average discharge burnup of 12.4 MWd/kgU. The bi-directional 4-bundle shift fuelling scheme provided good time-averaged axial power profile without significant depression at the center of channel.

The 600 FPD simulation results show that the maximum channel powers were maintained below the license limit of the CANDU 6 reactor. Also, the peak bundle powers during 600 FPD simulation were well below the limit.

From the above results, it can be concluded that the CANFLEX-RU fuel can be loaded safely in the CANDU 6 reactor.

References

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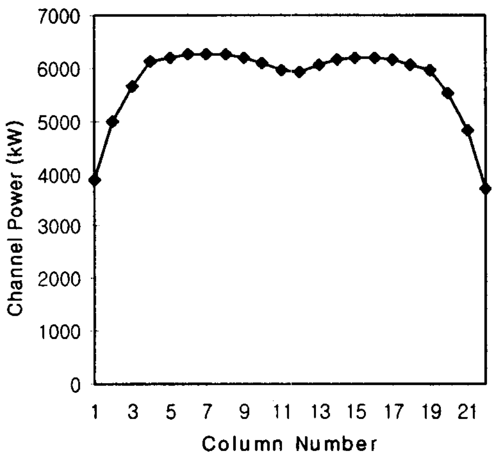

Figure 1 Time-averaged Channel Power (Row L)

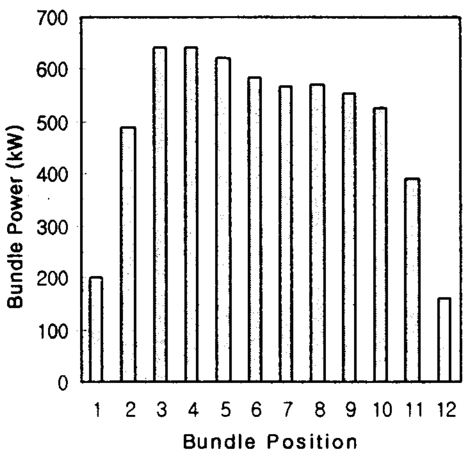

Figure 2 Time-averaged Axial Bundle Power(L-11)

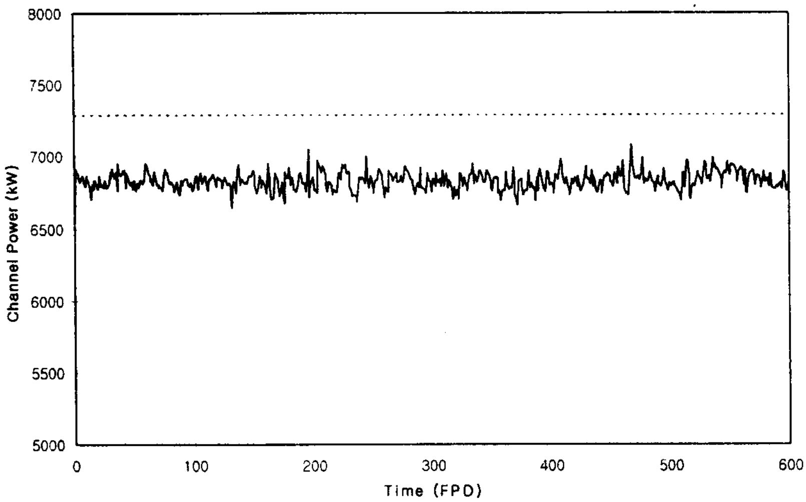

Figure 3 Peak Channel Power

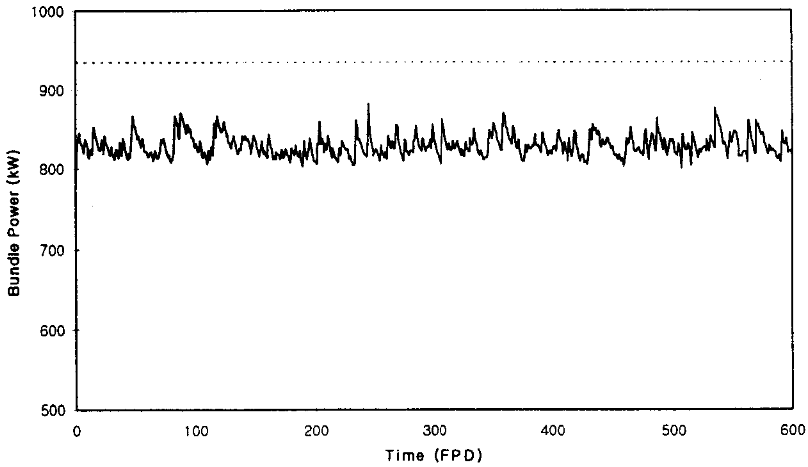

Figure 4 Peak Bundle Power