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# Core Analysis during Transition from 37-Element Fuel to CANFLEX-NU Fuel in CANDU 6

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**Abstract**

*An 1200-day time-dependent fuel-management for the transition from 37-element fuel to CANFLEX-NU fuel in a CANDU 6 reactor has been simulated to show the compatibility of the CANFLEX-NU fuel with the reactor operation. The simulation calculations were carried out with the RFSP code, provided by cell averaged fuel properties obtained from the POWDERPUFS-V code. The refueling scheme for both fuels was an eight bundle shift at a time. The simulation results show that the maximum channel and bundle powers were maintained below the license limit of the CANDU 6. This indicates that the CANFLEX-NU fuel bundle is compatible with the CANDU 6 reactor operation during the transition period.*

## I. Introduction

The CANFLEX(CANdu FLEXible fuelling) fuel[1] has been developed jointly by KAERI and AECL. 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 element in the inner rings.

The CANFLEX-NU(Natural Uranium) fuel bundle is expected to be loaded in the existing CANDU 6 reactor. Therefore, it is need to analyze the transition core from 37-element fuel to CANFLEX-NU fuel. Time-average calculation, instantaneous calculation and 1200 full-power-days refueling simulation were performed for the transition core analysis.

This paper presents the results of the 1200-day time dependent fuel-management simulation for the transition from 37-element fuel to CANFLEX-NU fuel in the CANDU 6 reactor.

## II. Calculation Procedure

### II.1 Reactor Model

Reactor core calculations were performed with a 3-dimensional full core model. Flux and power were calculated by 3-dimension using 44, 36 and 24 calculation mesh points in the x-, y- and z-direction respectively.

The simulation was performed by using the fuel-management code RFSP[2] which calculates 3-dimensional flux and power distributions for the core by solving the finite-difference neutron diffusion equation in 2-energy groups. Fuel tables for RFSP were derived with POWDERPUFS-V(PPV) module[2] which incorporated in the RFSP code.

### II.2 Modelling the Transition

The time-dependent refueling was simulated by taking 1-day refueling interval. The starting point was an instantaneous calculation of the equilibrium core loaded with 37-element fuel bundles fully. The simulation was divided into three parts. The pre-transition period extended from 0 to 300 full-power days, for which the reactor was fuelled only with 37-element fuel bundles by using a regular 8-bundle shift fuelling scheme.

During the transition period, refueling took place only with the CANFLEX-NU fuel bundles by using a regular 8-bundle shift fuelling scheme. The transition stage lasted from 300 days to 920 days, for which all of the 37-element fuel in the core had been replaced by CANFLEX-NU fuel. That is, it took 620 days to complete the transition from all 37-element fuel to all CANFLEX-NU fuel.

In the post-transition phase, the refueling continued with CANFLEX-NU fuel bundle until 1200 days, to estimate of the equilibrium core characteristics with CANFLEX-NU fuel.

### II.3 Time-average and Instantaneous Core Model

In the time-average calculation, the lattice cell properties are averaged over the fuel dwell-time of the fuel at each position in the core. The resultant flux and powers are indicative of what would be seen "on average" in the core. In reality, there would be perturbations about the time-average distribution, due to refueling, control rod action, and so on. The time-average channel power distribution serves as a reference, which the fuel engineers try to achieve during refueling.

In setting-up the time-average model, the core was divided into 7 irradiation zones, over which the average fuel discharge irradiation is constant. The water level in the zone control compartments was set to 50% full, which is a representative of the normal operating conditions.

At any given moment in the reactor's history, the power distribution is most likely different from the time-average power distribution. In particular, the instantaneous maximum channel and bundle powers are likely to exceed those calculated with the time-average procedure. The instantaneous calculation provides a "snapshot" of the core power and burnup distribution at some point in time. Every channel in the core was assigned an age which indicates the fraction of dwell-time between visits of fuelling machine to the channel. A channel with an age of 0 has just been refueled; a channel with an age of 1.0 has reached its target burnup and is about to be refueled. In the instantaneous calculation, the channel ages range uniformly from 0 to 1, with an increment of 1/380 (380 channels in the core) and a random distribution over the core.

### II.4 Time-Dependent Refueling Simulation

To estimate parameters such as the peak power and refueling ripple, a time-dependent refueling simulation was performed for 1200 full power days by using the SIMULATE module in RFSP code. In the refueling simulation calculation, "History Based Local Parameter"[(2)] option was used by allowing spatial and bulk control. Individual channels were selected for refueling, and flux and powers were calculated at 1 day interval. The starting point in the simulation was the instantaneous model. In selecting channels for refueling, "Auto-Refueling Method"[(3)] was used.

## III. Results and Discussion

The peak bundle power variation of the CANFLEX-NU fuel and the standard 37-element fuel are shown in Fig. 1. From this result, the maximum value of the peak bundle powers in the transition period has occurred in the CANFLEX-NU fuel, and the maximum peak bundle power was 846 kW at 848 day. This maximum bundle power is much below than the license limit of 935 kW for CANDU 6 reactor.

The variation of the peak channel power during 1200 FPDs is shown in Fig. 2. It is shown that the maximum value of the peak channel power was 6967 kW at 644 day, which is well below the license limit of 7300 kW.

Table 1 summaries the results of the transition calculation from 301 full power days to 1200 full power days. The maximum channel power peaking factor(CPPF) was 1.108 and the average zone controller level maintained near 50%. These values are compatible with the normal operating condition of CANDU 6 reactor.

## IV. Summary and Conclusion

The transition from 37-element fuel to CANFLEX-NU fuel in a CANDU 6 reactor has been simulated for 1200 full power days by taking 1-day refueling interval.

It is shown that variations of the peak channel power during the transition period are well below the limit value of 7300 kW and also shown that the maximum CANFLEX-NU bundle power during the transition period are well below the limit value of 935 kW.

The maximum CPPF is 1.108 and the average zone controller is maintained near 50%. These values are compatible with the normal operating condition of CANDU 6 reactor.

Average discharge burnup of the CANFLEX-NU fuel is shown to be 171 MWh/kgU, which is very similar to that of the standard 37-element fuel for CANDU 6 reactor. The refueling is about 2 channel per day, which means that fuelling rate is almost the same as that of the standard 37-element fuel.

From the above results, it can be concluded that the CANFLEX-NU fuel has compatibility in the current CANDU 6 reactor during the transition period.

## References


1. H.C. Suk and A.D. Lane et al, "CANFLEX as a CANDU Advanced Fuel Bundle", Proceedings of the 5th International Topical Meeting on Nuclear Thermal Hydraulics, Operations and Safety, Apr. 14-18 1997, Beijing, China, pp U1-1 U1-16 (1997).
2. D.A. Jenkins and B. Rouben, "Reactor Fuelling Simulation Program - RFSP: User's Manual for Microcomputer Version" AECL Report TTR-321 (1993).
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**Table 1 Summary Results of Simulation**
**(From 301 FPD to 1200 FPD, CANFLEX-NU)**

| | | |
|---|---|---|
| Peak Channel Power (kW) | Max | 6967.0 |
| | Avg | 6783.2 |
| | Min | 6619.0 |
| Peak Bundle Power (kW) | Max | 846.5 |
| | Avg | 812.3 |
| | Min | 776.3 |
| ZCU Level (%) | Max | .7980 |
| | Avg | .4985 |
| | Min | .2590 |
| CPPF | Max | 1.1080 |
| | Avg | 1.0617 |
| | Min | 1.0370 |
| Outer Core Burnup (MWh/kgU) | Max | 213.8 |
| | Avg | 164.5 |
| | Min | 108.4 |
| Inner Core Burnup (MWh/kgU) | Max | 240.6 |
| | Avg | 182.0 |
| | Min | 146.6 |
| Refueling (#/Channel) | Inner | .7057 |
| | Outer | 1.2835 |
| | Total | 1.9892 |

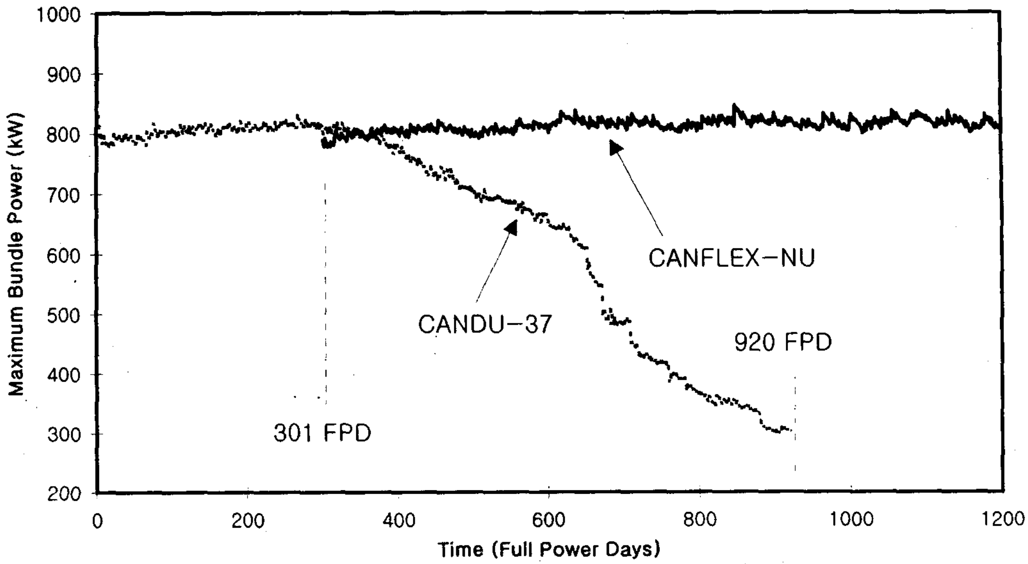


Fig. 1 Variation of Peak Bundle Power During 1200 FPD

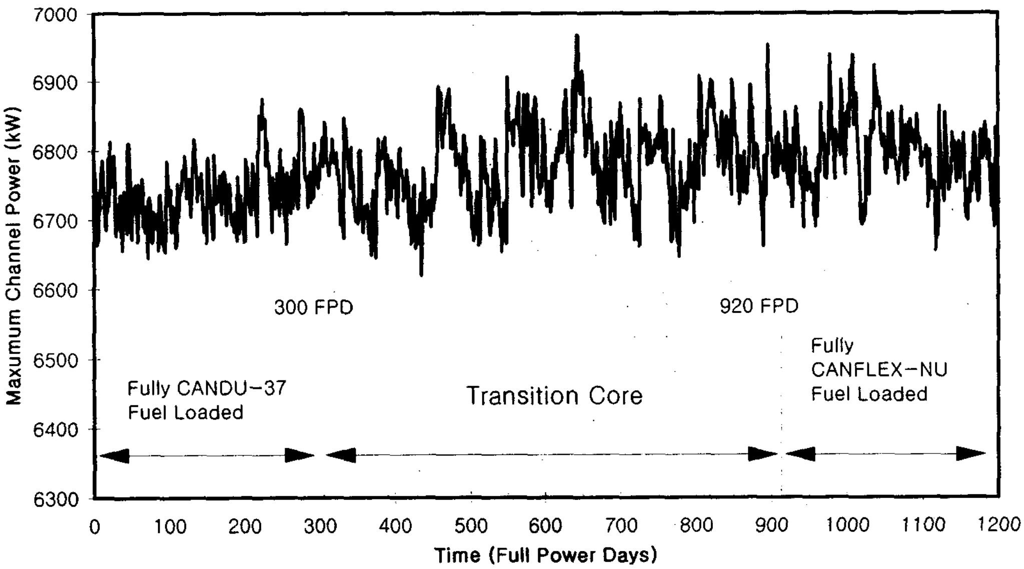


Fig. 2 Variation of Peak Channel Power During 1200 FPD