STATUS REPORT ABOUT CANDU TYPE FUEL ACTIVITIES IN ARGENTINA

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ABSTRACT

Domestic fuel performance in Embalse NPP during the last two years has been excellent without a significant occurrence of fuel failures. The defect rate level was reasonably low with a lowest value of 0.02 % in 2002.

The implementation of fuel design optimizations to increase U content was fully completed by the end of year 2000. The in-reactor performance was not affected and shows the high degree of maturity reached for both, the design and the manufacturing procedures and capabilities.

A feasibility study for the utilization of SEU in Embalse NPP mainly conducted by NA-SA and AECL is almost completed. Some fuel related activities are still in progress. As part of them fuel behavior simulations using simplified power histories were performed to assess the influence of SEU fuel burnup extension.

1 General Overview

This report presents the main activities performed in Argentina related with the type of nuclear fuel used in the Embalse Power Station. Embalse has a CANDU-6 type reactor that is operating since 1983. The organizations involved in nuclear fuel activities in Argentina are CNEA (fuel design and engineering issues), CONUAR (domestic fuel manufacturer) and NA-SA (operator of the nuclear power stations).

This presentation covers the following areas: fuel performance, fuel design and engineering activities, fuel fabrication and advanced programs.

2 Fuel Performance

During the last two years, 2001 and 2002, more than 10000 bundles have been irradiated in Embalse NPP. Almost all of them were fabricated by CONUAR in Argentina. Table 1 provides the relevant information for this period. During both years the average discharge burnup was around 7400 MWd/tU and the failure rate dropped to a 0.02 % value during 2002. Only three FA in 2001 and 1 FA in 2002 were declared failed by the power station. The overall failure rate for the last 5 years is 0.04 %. This is a remarkable improvement respect past failure rates reported in previous **International Conferences on CANDU Fuel** (1).

Table 2 presents information related with the fuel failures occurred during 2001 and 2002. In only one case out of four the defected fuel assembly was detected during the post irradiation visual inspection. In another case the failed fuel assembly was detected during the wet sipping test and in the other two cases the failed fuels were not identified. The failed fuel rod detected during the visual inspection showed hydrides in both end cap-sheath welding areas and also an opening in one of them. The reason of the failure was not precisely determined.

3 Fuel Design and Fuel Fabrication Issues

The design of the fuel for Embalse has reached a high maturity state. The design of the main components of the fuel assembly remains very stable and only minor changes were introduced to cover manufacturing requirements, to reduce costs or to improve fuel reliability

Despite the excellent performance of the fuel a real need to reduce costs still remains in order to keep the competitiveness of the nuclear energy.

Fuel design contributions developed by CNEA toward this objective were presented during the 1997 CANDU Conference [1]. To increment the U content, several design optimizations were proposed and developed. In a first stage, these modifications affected only the dishing volume and the diameter of the fuel pellets and the length of the fuel stack. Three ways have been considered for the last one: a reduction of the nominal axial gap between fuel pellets stack and endcaps, a reduction of the fuel stack length tolerance and a small increment of the length of the fuel bundle. Table 3 shows the dates when each one of the design changes were fully implemented in the fabrication line. All the modifications were completely implemented by the end of 2000. Since then all the domestic fuels assemblies irradiated in Embalse had those changes and the overall performance of the fuel assemblies showed no detrimental effects.

The benefits of these design optimizations in terms of U content increment are reported in Table 4 (2).

The increment of the density of the fuel pellets also produces good results but its application depends on another factors like powder quality and pellet fabrication technology. During the last three years the average pellets density remained higher than 12.61 g/cm^3.

Design optimizations to reduce fuel-manufacturing cost are developed in a close agreement with the fuel manufacturer.

4 Fuel Fabrication capabilities

During the last 4 years the manufacturing line of CONUAR was improved considerably with new equipment (3). The main modifications were oriented to increase the reliability of the fuel, to reduce intermediate stocks and also to reduce manufacturing costs. These modifications included the replacement of the end cap welding machine and the complete automation of the fuel rod fabrication line.

The advantages of these improvements are summarized in Table 5. Figures 1, 2 and 3 present pictures showing the new facilities for fuel rod fabrication. The most important results are related with the significant reduction of the rejection rate, another advantages are shown in Figure 4.

5 Embalse SEU Fuel Program

NA-SA and AECL has been analyzing under the framework of a co-operative program the feasibility of using Slightly Enriched Uranium (with 0.9 w% ^{235}U) fuel in the Embalse nuclear power reactor. Using SEU fuel would produce a significant increase in the fuel discharge burnup, from 7.35 MWd/kgU currently achieved with natural-uranium (NU) fuel to about 14 MWd/kgU. This would lead to a reduced fuel-cycle cost and a large reduction in spent-fuel volume per full-power-year of operation.

NA-SA and CNEA have already implemented the conversion of the PHWR Atucha I NPP from NU to SEU (0.85 % ^{235}U) during the 90´s with excellent results.

Some activities related with the assessment of the Embalse fuel performance up to SEU typical burnups are still in progress. Among them CNEA has recently performed preliminary calculations to evaluate the typical behaviour of the fuel in nominal design conditions.

To perform these studies NA-SA provided typical instantaneous fuel power distributions at different fuel burnups (3). Simplified power histories were built from those distributions. Figures 5 and 6 show the power distributions and Figure 7 shows the simplified power histories.

Main parameters analyzed were fuel center temperature, internal gas pressure and cladding strains. Fuel calculations were performed using ELESIM mod.9 and mod.10 codes. These preliminary results are encouraging and allow to predict a very limited impact of the higher burnup on the fuel performance for the current design conditions. As an example Figure 8 shows the evolution of central temperature for both power histories.

6 Final Remarks

Domestic fuel performance in Embalse NPP during the last two years has been excellent without a significant occurrence of fuel failures. The failures level was reasonably low with a Fuel Failure rate of 0.04 % for the last 5 years (1998-2002).

The implementation of fuel design optimizations to increase U content was fully completed by the end of year 2000. The in-reactor performance was not affected and shows the high degree of maturity reached for both, the design and the manufacturing procedures and capabilities.

During the last 4 years a significant improvement of the manufacturing process was achieved, mainly with the complete automation of the fuel rod fabrication line.

A feasibility study for the utilization of SEU in Embalse NPP conducted by NA-SA and AECL is almost completed. Fuel behavior simulations using envelope power histories were performed by CNEA as part of the assessment of the influence of SEU fuel burnup extension. This work is still in progress.

7 References

(1) L. Alvarez, J. Casario, R. Olezza, 5th International Conference on CANDU Fuel, Toronto, CANADA, September 1997.
(2) R. Lamuedra (CONUAR), personal communication, May 2003.
(3) J. Fink (NA-SA), personal communication, August 2003.

Table 1: Relevant data related with the irradiation and performance of the fuel elements in Embalse NPP.

Concept	YEAR	
	2001	**2002**
Fuel bundles irradiated	5416	4770
EFPD	353,12	304,82
Loading factor	97,54%	83,57%
Average Discharge Burnup [MWD/t.U]	7423,6	7315,4
Failed Fuel Assemblies	3	1
Annual Failure Rate	0,06%	0,02%
Fuel Failure rate during the last 5 years 1998-2002	0,04%	

Table 2: Information regarding fuel failures occurred during 2001 and 2002

Year	Channel	Failed FA identified by	Position in the channel	Discharge Burnup [MWd/tU]
2001	N17	Visual Inspection	11	5575,9
	K08	Wet Sipping	9	1943,9
	M15	Not identified		4752.9 (*)
2002	K13	Not identified		7829,0 (*)

(*) Average burnup of the 8 FA replaced.

Table 3: Dates when each one of the design changes to increase U content was finally implemented for fabrication

Dishing depth reduction	July 97
First increment of FP diameter	October 97
Stack length modifications	May 98
Second increment of FP diameter	November 2000

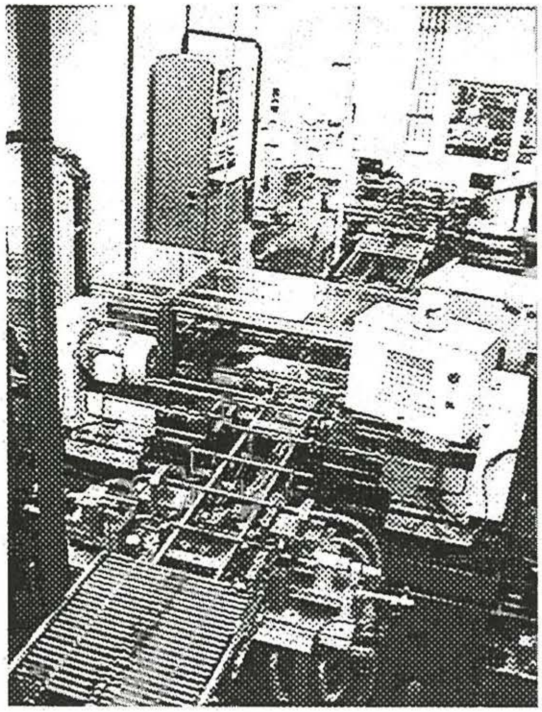
Table 4: Evolution of the U content in the Embalse fuel bundles during the last three years

Year	Average U content [kg]	Minimum U content [kg]
2001	18.978	18.941
2002	19.008	18.952
2003	19.000	18.949

Table 5: Main advantages of the new fuel rod fabrication line

Failure rate < 2 ppm **(2 failed FE/15000 FE means more than 1.500.000 weldings without failures)** **Self paid after less than 5 years** **Productivity improvement: 22%.**

Figures 1 and 2: New facilities for fuel rod fabrication – Cladding Machining and Endcap welding



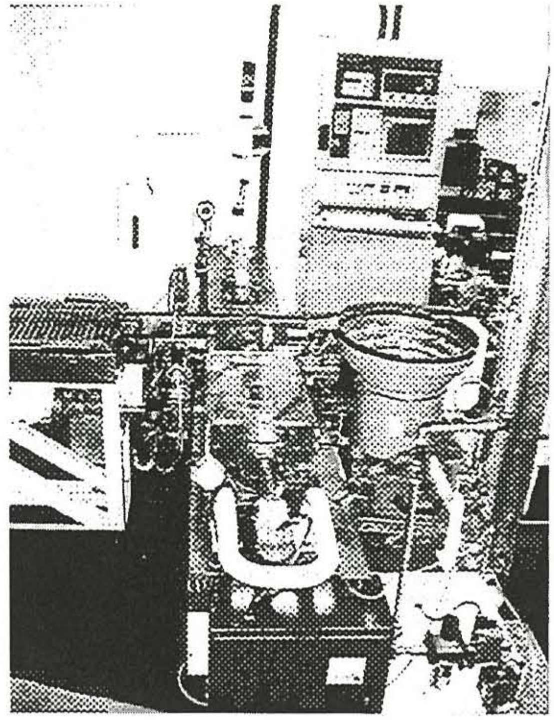


Figure 3: New facilities for fuel rod fabrication – General View

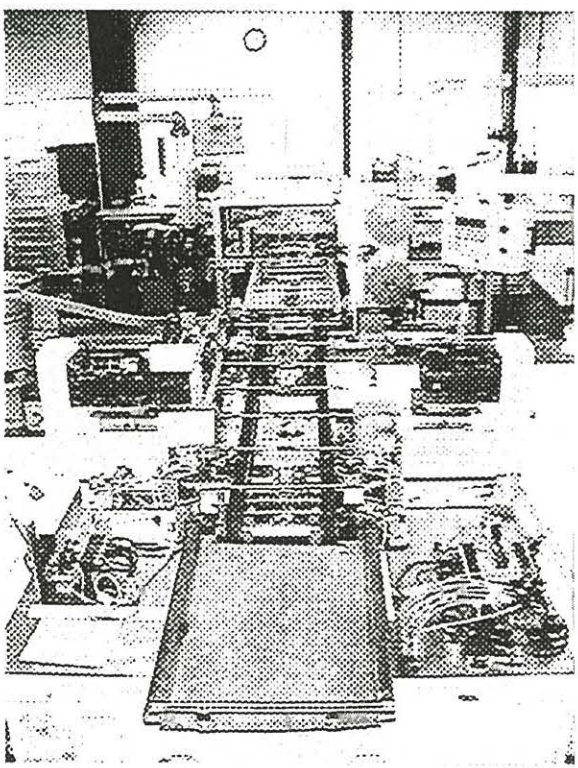
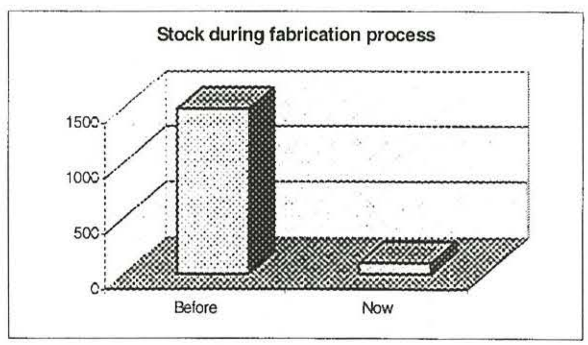


Figure 4: Main advantages of the new fuel rod fabrication equipment at CONUAR



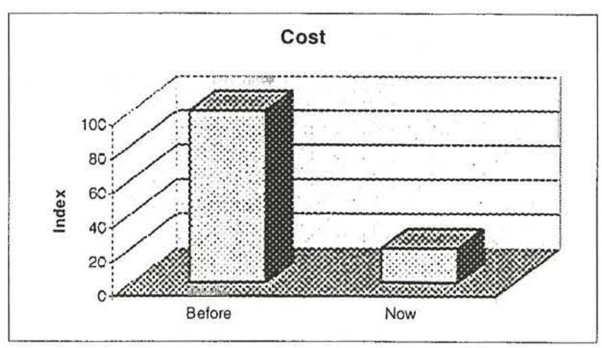


Figure 5: Linear Powers vs Rod Burnups for a Representative Instantaneous Burnup Distribution of a Two Burnup Region SEU Core, with 2 bs Refuelling

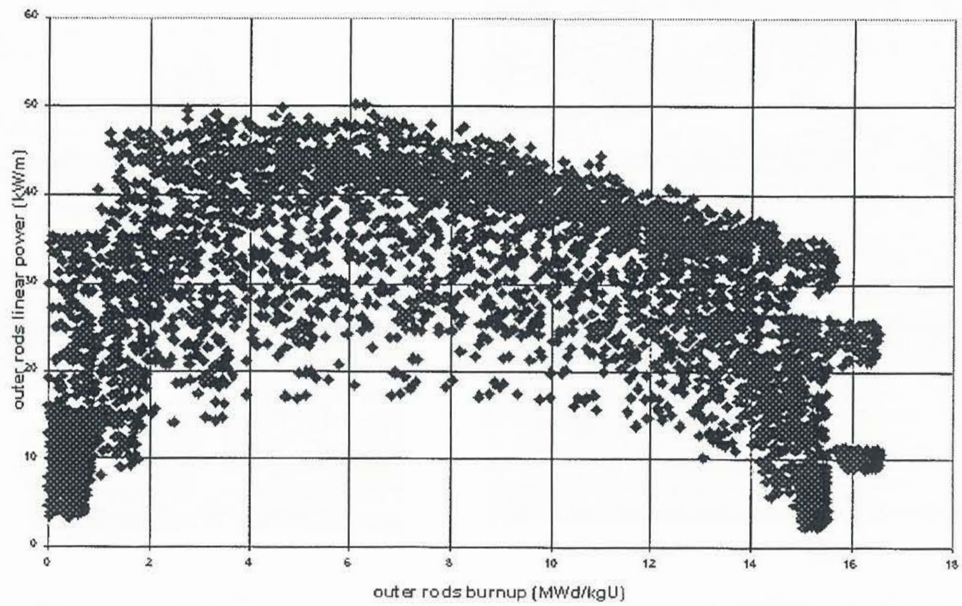


Figure 6: Linear Powers vs Rod Burnups for a Representative Instantaneous Burnup Distribution of a Two Burnup Region SEU Core, with 4 bs Refuelling

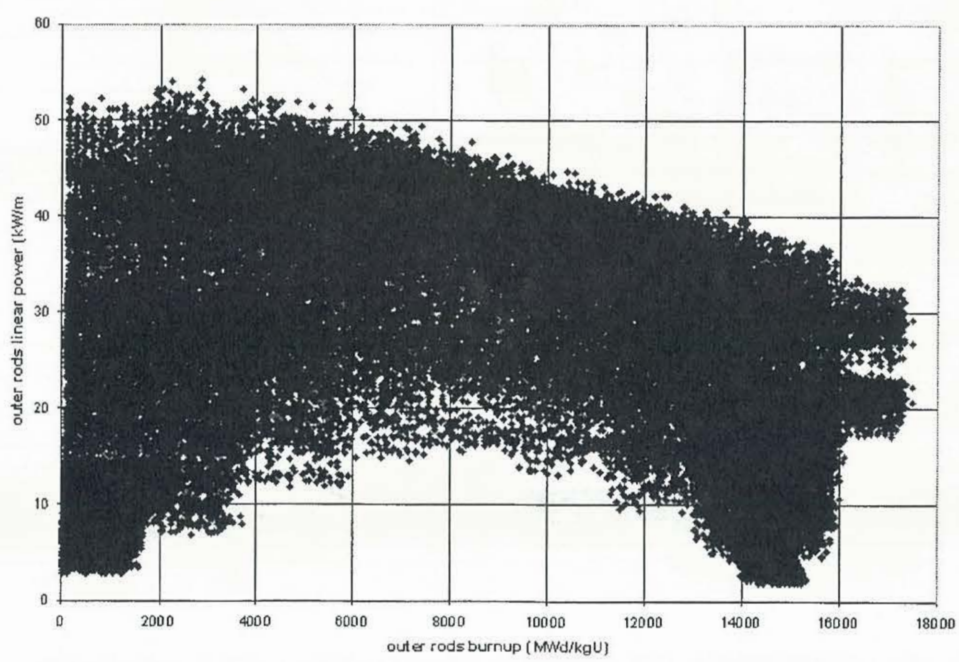


Figure 7: Simplified power histories

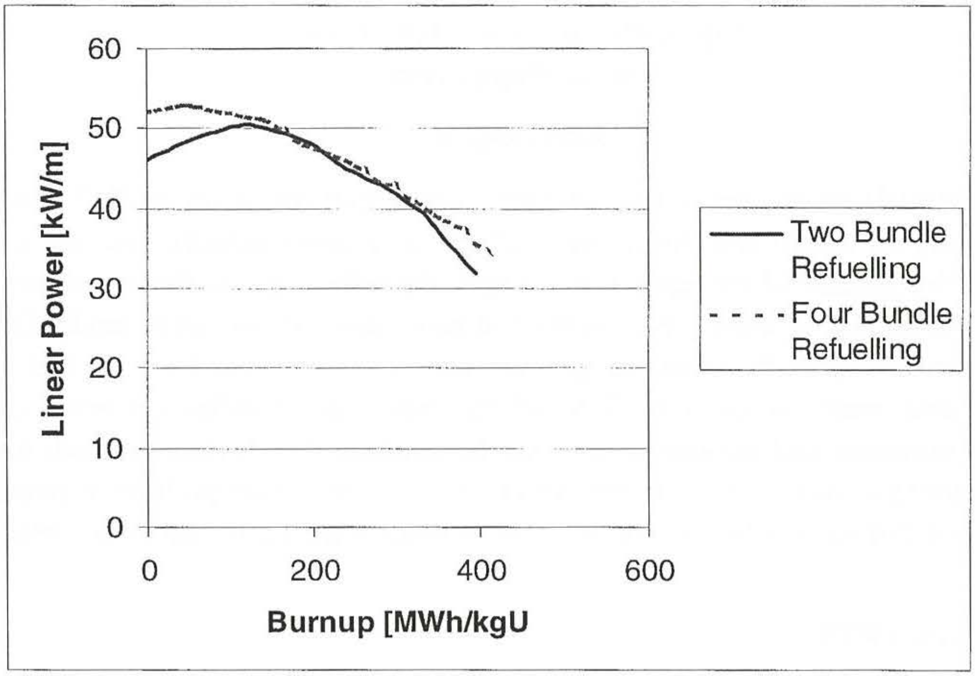


Figure 8: Center temperature calculations