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NUCLEAR FUEL PERFORMANCE IN EMBALSE NPP, DESIGN OPTIMIZATIOS AND MANUFACTURING IMPROVEMENTS

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ABSTRACT

Fuel performance in Embalse Nuclear Power Plant since the beginning of the operation of the commercial fuel manufacturing plant has been encouraging. Failure rates because of manufacturing flaws during the last 3 years is discussed. The total manufacturing failure rate is strongly affected by some "defect excursions". The first part of this paper presents the evolution of the failure rate and describes the most important excursions.

Despite the good performance of the fuel, new trends in the energy market require more economic fuels. Domestic fuel design optimizations towards this objective are discussed. These changes are mainly referred to an increment of the uranium content in the fuel. Another design changes that are directed to reduce the fuel manufacturing cost are also described. This modifications are in progress and under a qualification program.

New manufacturing equipments have been incorporated to reduce the cost of the fuel and to increase the fuel reliability. Some of them have been completely qualified and are fully operational.

1 General Overview

Embalse Nuclear Power Plant is a CANDU-6 type reactor that is operating since 1983. At the very beginning of the operation, the fuel was supplied by Canadian manufacturers. In 1985 the domestic supply started, first from a pilot plant and then from a commercial fuel manufacturer.

Based on the basic specifications of AECL, the detailed design of the fuel was completed by CNEA in 1984 and no significative changes were introduced since that time.

2 Fuel Performance

At the present, as we can see in Table 1, more than 30000 FA produced by our local commercial manufacturer have been irradiated in Embalse NPP. The average burnup of these fuels was approximately 7400 MWd/tU and the overall failure rate, after almost ten years of domestic supply, is 0.18 %. Fuel performance during the beginning of the operation of our local manufacturer was presented in previous **International Conferences on CANDU Fuel.**

Relevant data regarding the domestic supply of fuels to Embalse NPP during the last four years is presented in Figures 1 and 2. More than 3000 fuel bundles were delivered by the fuel manufacturer to the power station each year. Figure 2 shows the cumulative number of failed fuel bundles in this period and the failure rate for each year. This rate was less than 0.2 % in 1993 and then jumped to 0.4 % in 1995. In 1996 the failure rate was again very low. Although some fuels manufactured during 1996 are still into the reactor, the activity level of the primary coolant is very low so we expect that the good performance of these fuels will remain at that level until the end of their irradiation.

The evolution of the failure rate for each shipment of fuels manufactured during 1995 was analyzed in Figure 3. Shipment 03/95 had the maximum failure rate (1.2 %) and shipments 04/95 and 10/95 were also rather high, around 0.6 %. Some correlations with fuel manufacturing and control records suggest that there may be a relation between the failures and some batches of the graphite coating process. Although further investigations are necessary to confirm these findings, it is clear that failures are part of a "failure excursion". The same might be demonstrated for shipment 10/95 but related with the endcap welding process. The failure rate corresponding to the "failure excursions" modifies the overall fuel failure rate for the whole year. Table 2 shows relevant information for the last four years, including the failure rate without considering the "failure excursions". This rate is 0.10 - 0.15 %, depending on how many fuels are considered as part of the failure excursion.

Figure 4 shows relevant information for fuels manufactured during 1996. In this case there is only one failed fuel and therefore the failure rate is very low.

3 Design Optimizations

Despite the acceptable performance of the fuel, new trends in the energy market in Argentina require more economic fuels. To keep the competitiveness of the nuclear energy against power plants fuelled with gas it is necessary to reduce the cost of the nuclear fuel.

Fuel design contributions developed by CNEA toward this objective are related with the increment of the U mass in the FA and with the reduction of the fuel manufacturing cost. To increment the U content, several design optimizations have been proposed and developed. In a first stage, this modifications affect only the dishing volume of the fuel pellets and the length of the fuel stack. Three ways have been considered for the last one: a reduction of the axial gap between active length 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 benefits of these design optimizations. The increments of U content are presented separately for each change and the cumulative increment is also reported.

As seen in Table 3, the maximum increment of U content is produced by the reduction of the dishing volume. An additional increment is also possible through the manufacturing of fuel pellets with diameters close to the upper limit of the current design specification.

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.

All optimizations were analyzed by CNEA's Fuel Engineering & Design Branch and calculations with ELESIM Mod.9 and Mod.10 were performed to evaluate the operational parameters. As an example, Figure 5 shows results for the effectiveness of the new dishing volume.

New optimizations, like the increment of both, fuel pellets and fuel sheath diameters are under analysis and, depending on the results, will be applied in the near future.

Design optimizations to reduce fuel manufacturing cost are developed in a close agreement with our domestic fuel manufacturer. Endcap welding without previous endcap pickling and endplate welding without pickling the endplates have been qualified and are operating without any problem. In the near future we expect to analyze the elimination of the pellet side grinding. Modifications of some tolerances and specifications requirements will also be considered.

4 Manufacturing Improvements

After almost 10 years of domestic supply of fuels to Embalse NPP the main concerns about factors from fuel manufacturing that might be affecting fuel performance are related with: endcap welding, fuel sheath integrity, brazing influence and hydrogen content into the fuel element. Several manufacturing equipments associated with this factors have been improved by the fuel manufacturer with the assistance of CNEA to increase fuel reliability and economy. Qualification of the improved equipments was also performed with the participation of CNEA.

5 Conclusion

Fuel performance in Embalse NPP of fuel bundles produced by the domestic commercial fuel manufacturer during the last 4 years has been, in general, quite acceptable. The overall failure rate for this period was 0.18%. There were some "failure excursions" that had a strong influence on that figure. Without considering those "failure excursions" the failure rate should be 0.10 - 0.15 %. Despite the good performance, fuel design optimizations are necessary to reduce the fuel cost and also the fuel manufacturing cost. Some of these changes that represent an increment up to 1.75 % in the U content have been qualified by CNEA and are been applied for fuel manufacturing. The first series of fuel bundles with the new design are been irradiated in Embalse NPP without any indication of abnormalities. Fuel reliability is been increased with new fuel manufacturing technologies and the improvement of manufacturing equipments.

Table 1: Overall Domestic Fuel Performance in EMBALSE NPP

Fuel Bundles Irradiated	> 30000
Average Burnup	~ 7400 MWd/tU
Overall Fuel Failure Rate	0.18 %

Table 2: 1993-1996 Domestic Fuel Performance in EMBALSE NPP

Fuel Bundles Irradiated	16401
Failed Fuel Bundles	30
Fuel Failure Rate	0.19 %
Fuel Failure Rate (Without "Failure Excursions")	0.10 - 0.15 %

Table 3: Increment of the fuel bundles U content

Design optimization	Increment (separately) [%]	Increment (cumulative) [%]
Dishing Volume	1.25	1.25
Axial Gap & Active Length	0.33	1.58
Fuel Pellet Diameter (Within current specification)	0.17	1.75

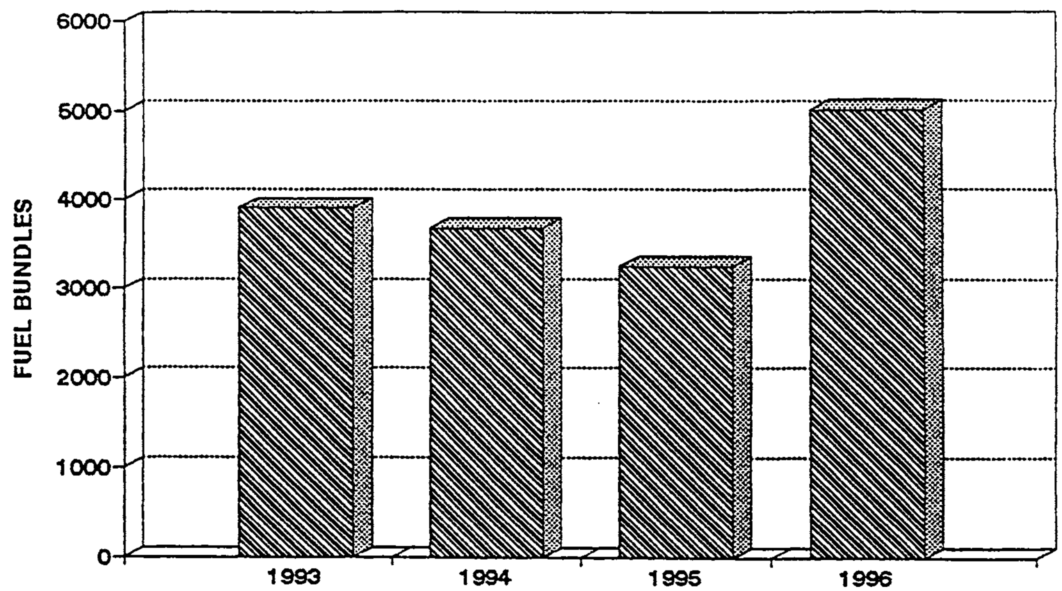

Figure 1: Fuel bundles supplied to Embalse NPP by the commercial fuel manufacturer during the last four years.

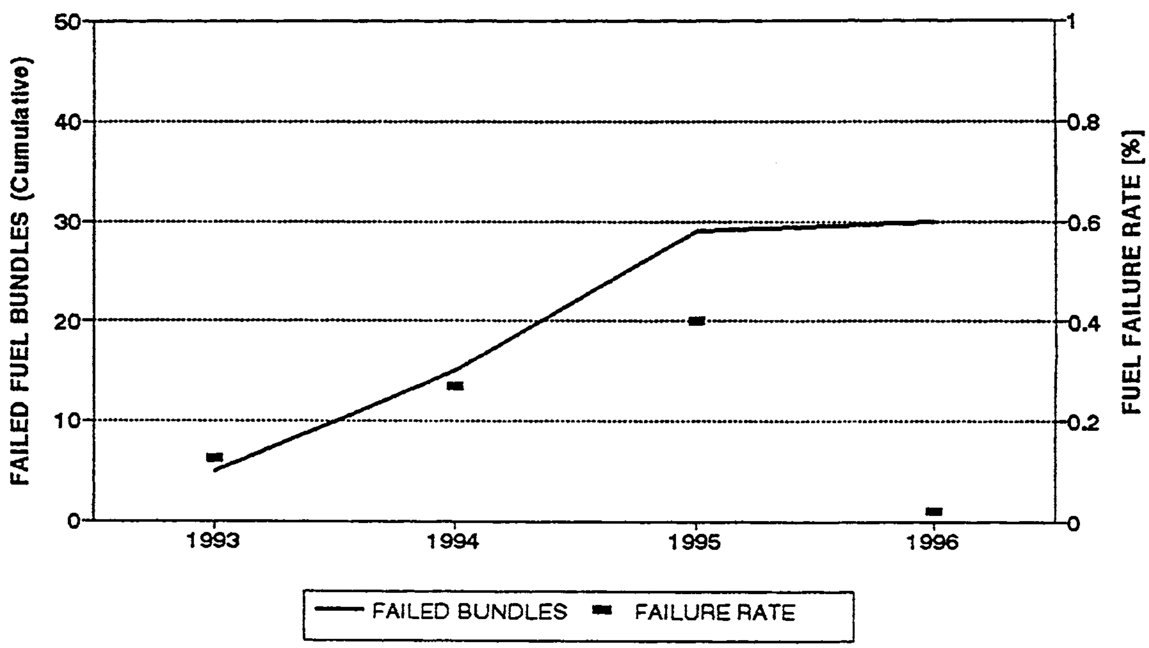

Figure 2: Domestic failed fuel bundles and fuel failure rate during the last four years.

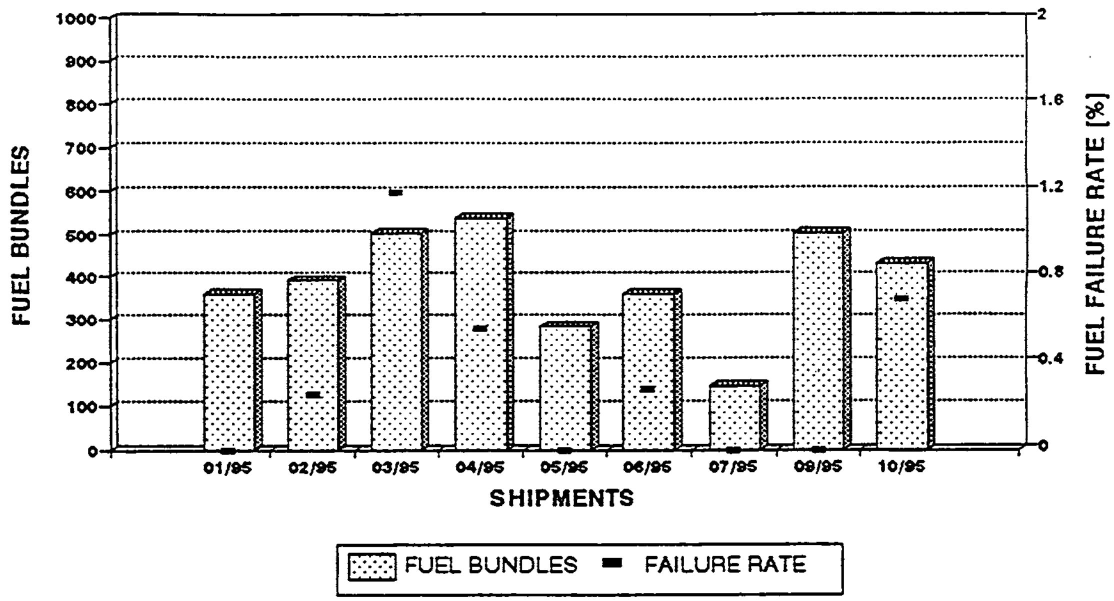

Figure 3: Evolution of the fuel failure rate for each shipment of fuels manufactured during 1995.

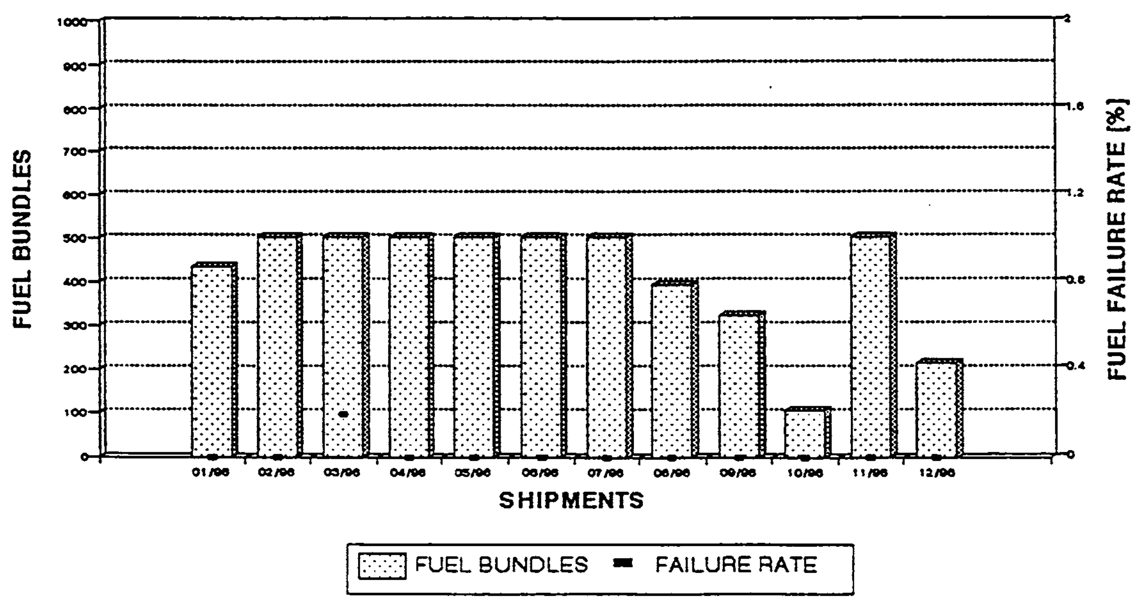

Figure 4: Evolution of the relevant data for each shipment of fuels manufactured during 1996.

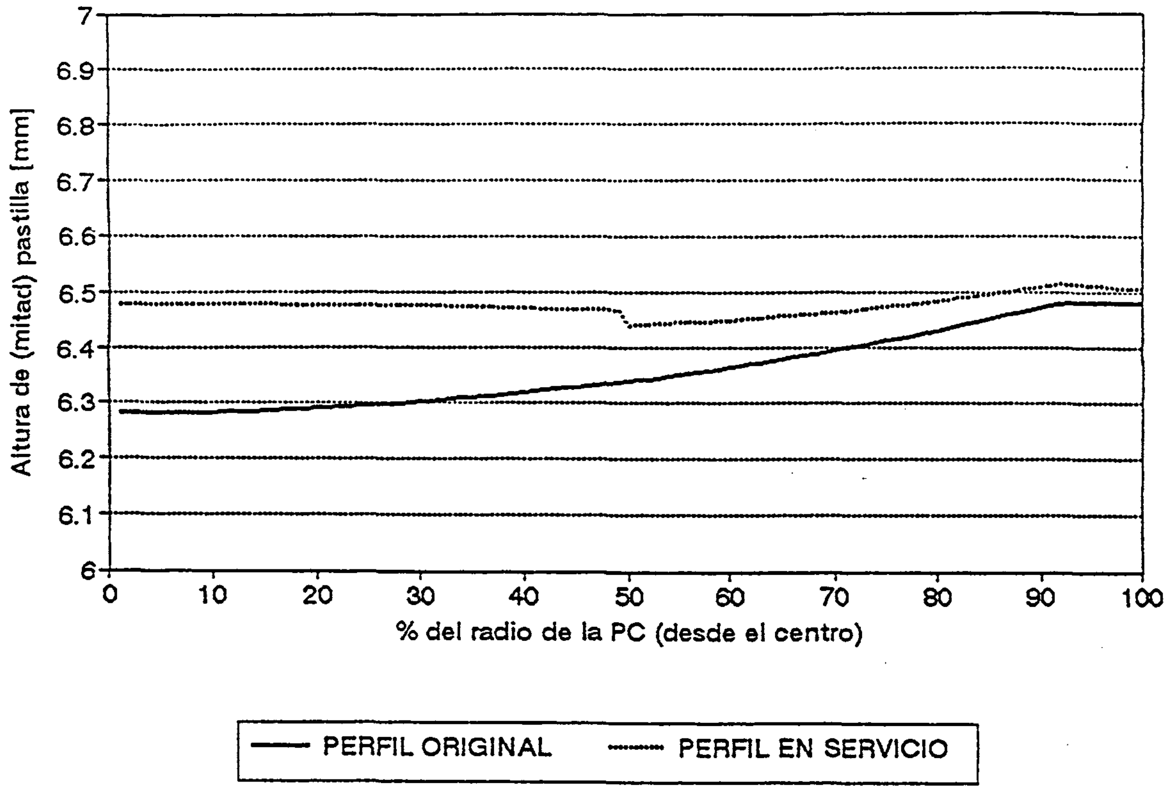

Figure 5: **Effectiveness of the dishing volume for the new design of fuel pellets**