FIVE YEARS OF SUCCESSFUL CANDU-6 FUEL MANUFACTURING IN ROMANIA

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ABSTRACT

This paper describes the evolution of CANDU-6 nuclear fuel manufacturing in Romania at FCN[1] Pitesti, after the completion of the qualification in 1994. Commercial production was resumed early 1995 and fuel bundles produced were entirely delivered to Cernavoda Plant and charged in the reactor. More than 12,000 fuel bundles have been produced in the last five years and the fuel behaved very well. Defective bundles represents less than 0.06 % from the total irradiated fuel, and the most defects are associated to the highest power positions.

After qualification, FCN focused the effort to improve braze quality and also to maintain a low residual hydrogen content in graphite coated sheaths.

The production capacity was increased especially for component manufacturing, appendages tack welding and brazing. A new graphite baking furnace with increased capacity, is under design. In the pelleting area, a rotary press will replace the older hydraulic presses used for pelleting.

Plant development take into consideration the future demands for Cernavoda Unit 2.

1. INTRODUCTION

CANDU-6 nuclear fuel is produced in Romania by "FABRICA DE COMBUSTIBIL NUCLEAR " (FCN) placed near Pitesti, a subsidiary of NUCLEARELECTRICA S.A.

Nuclear fuel plant resumed CANDU-6 fuel production in 1995, following an intensive upgrading and qualification program, achieved in co-operation with AECL and Zircatec Precision Industries Inc., Canada. The history of CANDU-6 fuel manufacturing program in

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[1] FCN - "Fabrica de Combustibil Nuclear" means "Nuclear Fuel Plant".

Romania is known by most people of nuclear fuel world, especially by those involved in CANDU nuclear fuel. More details may be found in few papers which have been presented to conferences organized by IAEA and AECL [1] [2] [3] [4].

In short, Romania produced before 1991 about 33,000 CANDU-6 fuel bundles.

AECL-Ansaldo Corporation did not recognize the stock fuel as having a well defined and acceptable quality and recommended qualification of fuel manufacturing in accordance with Canadian standard CSA Z299.2. These was accomplished in 1994, including a demonstrative manufacturing of 200 fuel bundles which were charged in the first core load.

The fuel manufactured during demonstration phase and since 1995 behaved very well in reactor. More than 12,000 fuel bundles manufactured at FCN have been discharged from the reactor with an average burnup over 170 MWh/kgU reported to equilibrium core. A limited number of bundles were reported to be defected in reactor. The percentage of defected fuel bundles is less than 0.06 % representing about 0.002 % in terms of fuel elements.

2. CANDU-6 FUEL PRODUCTION

2.1. Uranium Sources

Pellets used for fuel manufacturing are coming from three sources.

a) Pellets manufactured from UO2 powder, supplied by Feldioara Plant. This is a qualified uranium dioxide powder supplier in Romania.

b) UO2 pellets recovered from stock fuel manufactured before 1991. Fuel bundles are dismantled and pellets are carefully handled so all identification and traceability requirements are fulfilled. All acceptable pellets are loaded in new fuel elements. The old end pellets are discarded.

c) Pellets manufactured from UO2 powder produced in FCN from recycled uranium. Recycled material includes scrap and rejected pellets from stock fuel. Rejection may be decided primary after the investigation of the original HD or may be done after quality re-verification.

Contribution to the material inventory is shown in Table 1.

There is no intention to enter in details of work. We apply for any kind of pellets an unique specification and there are no significant differences regarding density, chemistry and visual aspect.

We combine stock pellets with new end pellets to ensure the actual length of the pellet column. Pellets from different sources seems to behave very similar in reactor.

2.2. Zircaloy Materials

a) Zircaloy-4 cladding tubes are supplied now by Zircatec. Former contract with Sandvik is almost concluded, small quantities of tubes remaining to be delivered by this company. As the design is unique and similar to those used for stock fuel, there is no problem to use tubes from both suppliers, alternatively loading new or recovered pellets.

b) Barstock and sheet necessary for components as end caps, end plates, spacers and bearing pads are supplied by CEZUS.

2.3. Manufacturing Program

Under the pressure of financial constraints, the extent of production was limited to the quantity necessary to ensure recharge fuel for Cernavoda Unit 1. Total production attained more than 12,0000 fuel bundles by end of May 1999.

Evolution of fuel production during last five years is presented in Table 1.

As shown in this table the recovery of UO_2 pellets from stock fuel represents an important part of the manufacturing program.

2.4. Quality Achievements

High quality fuel represents the main objective for our plant. In the frame of QA system, FCN maintains a strong process control and QA surveillance.

For a time FCN focused the efforts on two aspects:

- braze quality including visual and metallographic requirements, and
- residual hydrogen in baked sheaths

Braze quality was improved mainly by two concurrent solutions.

One of them consists in producing components - spacers and bearing pads - with an optimized shape in condition of stable quality. The quality and endurance of punching tools ensure close tolerances which are essential to obtain good tack welding and braze joints. The appearance of braze joints was considerably improved.

The second solution was to accept only sheath with minimum three prior beta grains in HAZ. This may be achieved with appropriate control of process parameters during brazing heat treatment. The inspection was improved and now we are using a qualified visual inspection using visual examples combined with metallographic samples.

Residual hydrogen in sheath after graphite baking is maintained low. Typical values are actually around 0.12 mg per sheath. Two solutions have been used. First we have improved the redundancy of temperature monitoring system and secondly, the process control was enforced by monitoring residual hydrogen in graphite coated sheaths combined with monitoring of gas hydrogen in finished elements.

3. FUEL PERFORMANCE

Cernavoda Unit 1 frequently operated at power levels of 715-720 MW(e), in "turbine - follows-reactor" mode, that means higher that design rated electrical power of 706.5 MW(e) [7].

In the first fuel load containing Zircatec fuel, 6 channels have been loaded with fuel bundles manufactured during Manufacturing Demonstration. Reload fuel was entirely supplied by FCN.

By the end of May 1999, only 7 fuel bundles have been confirmed as defect. Some of them were very small and identification od the defect bundle was not possible.

Discharge burnup of the defect fuel was between 150 and 203 MWh/kgU. In one case the burnup is not reported, the defect bundle being part of a group supporting an swing 8 refueling operation, in the channel L8, similar with other 274 fuel channels.

As shown in Fig. 1 and Fig. 2 respectively, the defect bundle location pattern is very similar with those reported by Manzer et al., for Point Lepreau [5] in the period 1991-1992. An concentration of defect positions in the channels in the annular high power zone is also shown by Hyun-Taek Park et al., for Wolsong -1 [6].

The operation conditions can be summarized as follows:

- All defects occurred in high power channels;
- Majority of defects occurred in the second channel length - positions 7 to 10, towards the channel outlet where high coolant/sheath temperature exists;
- There is no evidence to show defects at low burnup, let say under 40 MWh/kgU; we appreciate the defect cause should be not a manufacturing defect;
- Defects occurred in both cooling loops;
- There is no indication to show the simultaneous apparition of defects.

The total defect rate, in term of bundle is less than 0.06 % corresponding to less than 0.002 % defective elements.

Our attention was focused on two manufacturing aspects. First of all we observed from process control data, some instability in end cap welding process in November 95. The records shows few tool replacements (electrode and electrical connection), however, the normal quality verification results show no indication of a lower weld quality.

As all defects appeared in high power bundles, the assumption that potential cause of defects could be a lower weld quality in some sporadic elements, seems to be not realistic.

The second aspect is related to presence of hydrogen in elements over the limit of specification (1 mg gas hydrogen per element). Indeed by the end 1995, we had some indications about a potential higher hydrogen content in a portion of fuel. The suspect fuel bundles were identified and a remake procedure was used. However it is possible some elements with abnormal hydrogen content remains in the fuel delivered to Cernavoda Plant.

Information coming from Cernavoda Plant [8] shows that maximum bundle power do not exceeded 872 kW per fuel bundle.

4. MANUFACTURING POTENTIAL

Basic capability achieved during plant qualification was maintained and developed. FCN procured two tack welding machines from ZPI being now qualified and used for current production. A new brazing device with two braze units was commissioned and qualified.

There is in advanced design phase a new graphite baking furnace with increased capacity.

FCN develop now co-operation with different Romanian companies which have been evaluated and accepted to produce specific machines and tools. There are, for example, at least two qualified suppliers for punching dies used for spacers and bearing pads.

FCN shall increase his production capacity in order to be able to supply nuclear fuel for two CANDU-6 units in few years. First major plant development will be created on pelleting area by introducing a rotary press in the production line. In a second phase FCN shall install new welding machines. These machines have been already ordered and the work is in good progress.

5. CONCLUSIONS

The Qualification of FCN as CANDU fuel supplier proves to be a realistic decision taken by the Romanian authorities. FCN maintained and even developed his capability to produce high quality CANDU-6 nuclear fuel.

A careful activity is performed in FCN in order to recover as much as possible from the stock fuel.

Fuel performance in Cernavoda Unit 1 is very good. We concentrate our efforts to produce the best fuel for this power plant and to stimulate the confidence of our Customer.

FCN works to increase his production capacity up to a level, able to satisfy the needs for two units of Cernavoda Power Plant.

6. REFERENCES

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TABLE 1. URANIUM SOURCES AND CANDU-6 FUEL PRODUCTION AT FCN PITESTI - ROMANIA

(FUEL BUNDLES)

YEAR	URANIUM SOURCES			TOTAL
	FELDIOARA PLANT	RECOVERED FROM STOCK	RECYCLED BY FCN	
1994	202	-	-	202
1995	1,678	-	-	1,678
1996	838	81	113	1,032
1997	962	2,308	1,240	4,510[1]
1998	2,046	881	784	3,811
1999[2]	107	1,144	-	1,251
TOTAL GENERAL	5,833	4,414	2,137	12,484

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[1] The figure includes 226 fuel bundles with depleted uranium.
[2] Reported quantity at end March 1999.

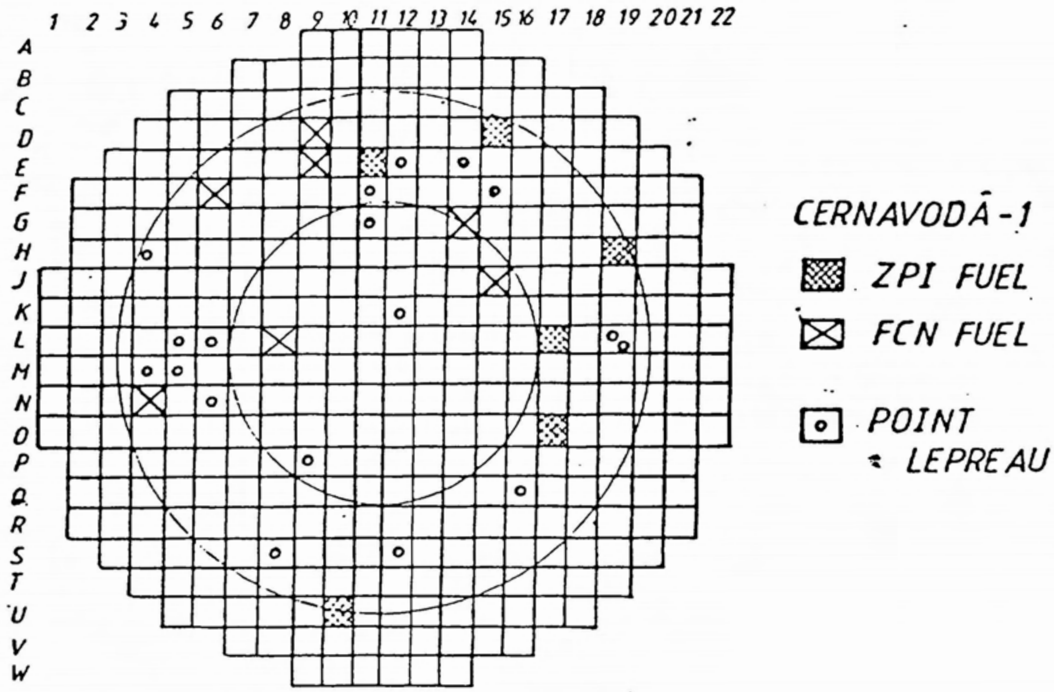

Figure 1. View showing Channels with Defect Fuel in Cernavoda-1 (1996/1999) and Point Lepreau (1991/1992).

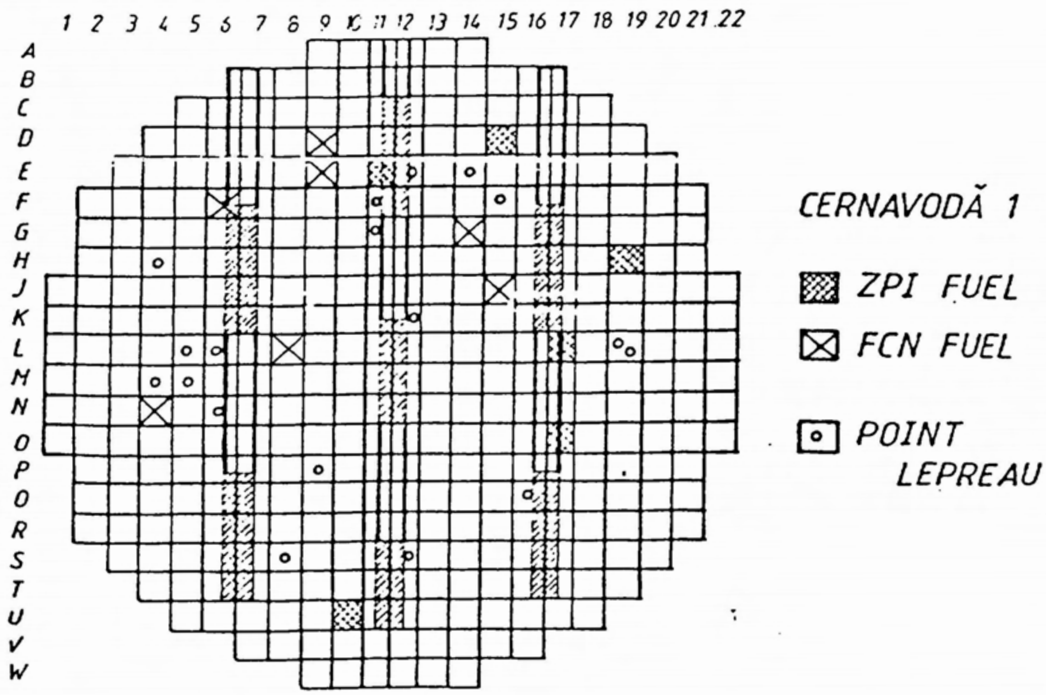

Figure 2. View showing Channels with Defect Fuel and Liquid Zone Controllers Location in Cernavoda-1 (1996/1999) and Point Lepreau (1991/1992).