EXPORTING TECHNOLOGY FOR CANDU FUEL MANUFACTURING TO THE PEOPLE'S REPUBLIC OF CHINA – A STIMULATING EXPERIENCE FOR THE ROMANIAN NUCLEAR FUEL PLANT

V. BAILESCU, G. BURCEA, V. TURCANU, C. STANCIU

S.N. NUCLEARELECTRICA S.A.
Fabrica de Combustibil Nuclear (FCN) – Pitesti
ROMANIA

ABSTRACT

Adopting CANDU type reactors to produce nuclear-generated electricity, Romania has also developed his capability to produce nuclear fuel. Since 1995, FCN Pitesti is the unique nuclear fuel supplier for Cernavoda CANDU Power Station. Fuel plant upgrading and qualification was achieved in co-operation with AECL and Zircatec Precision Industries Inc. The fuel bundles manufactured at FCN Pitesti proved to be of excellent quality, operating with a very low defect rate, all defected fuel being reported in the first period of the reactor operation.

It is a fact now that FCN has the capability to solve a wide variety of aspects one of the most significant being the development of new equipment and the increase of the capacity in order to cover the future nuclear fuel needs.

On this basis FCN was invited to contribute with his potential to a supplying contract with China National Nuclear Corporation – 202 Plant, for CANDU nuclear fuel technology.

Following an offer including several categories of equipment and technology, the option was for beryllium coaters and coating technology and training for end cap manufacturing.

The arrangements consider Romanian company as a sub-supplier, this option ensuring the consistence with the largest part of the supply for CANDU fuel technology, offered by Zircatec.

Two pieces of beryllium coaters have been produced and tested in Romania and the operating demonstration was made in the presence of Zircatec staff and Chinese delegates. The Chinese delegated were trained for complete operating modes and their ability to handle the equipment was certified accordingly. They also have been trained in the end cap technology and related quality inspection. The paper includes a short presentation of the equipment and associated work to fit the specified needs.

The involvement of the Romanian fuel plant in this contract could be considered as an extension of the previous co-operation with the Canadian partners on CANDU nuclear fuel and finally contributes to a wider co-operation bringing together people from different countries.

INTRODUCTION

Since 1995, the refueling of the first CANDU-6 reactor of Cernavoda NPP is made with fuel bundles produced in Romania at Pitesti nuclear fuel plant. As described in previous papers [1] [2], the plant was qualified in the frame of a joint program with AECL and Zircatec by the end of 1994. For this scope, few pieces of critical equipment were also transferred to FCN in the frame of this program or on a commercial basis.

After six years of CANDU-6 fuel production at FCN, we are right in saying that the essential was getting the confidence to people. Working together with AECL and Zircatec specialists and solving problems our engineers or technicians became aware of their own value.

The excellent fuel performance in reactor – there are no defects during last two years – contributes to the development of a creative attitude [3].

We are now working to increase the plant capacity and part of the equipment is already doubled or replaced with more productive one.

Being in permanent contact and commercial relation with Zircatec, FCN was invited to participate to the technology transfer to China National Nuclear Corporation – 202 Plant, with the scope to help them in developing CANDU fuel technology.

CO-OPERATION DESCRIPTION

As sub-supplier selected by Zircatec, FCN have offered equipment, know how and training for the following operations:

- Graphite coating/baking;
- Beryllium coating;
- End cap manufacturing and,
- End plate manufacturing.

The final Contract included only beryllium coating completely and training for end cap manufacturing.

The achievement of beryllium coating equipment included the following steps:

- Equipment design at FCN/
- Outline of Testing and Acceptance Plan ;
- Review/approval by Zircatec of the design and TAP;
- Equipment fabrication;

- Operational tests before shipment to FCN;
- Operating for TAP and Test Report;
- Test Report review and acceptance by Zircatec;
- Training and Certification for three specialists from 202 Plant;

The fabrication was made by a Romanian company in co-operation with a subsidiary of Bosch in Romania. Bosch is providing PLC,s similar to those produced by Alain Bradley and seemingly preferred in North America.

Process adjustment to fit Zircatec beryllium layer parameters and part of training was achieved on FCN equipment in order to keep the equipment clean and so avoiding licensing problems.

EQUIPMENT DESCRIPTION

Beryllium coating equipment consists of a double walls stainless steel vessel, connected to a high vacuum aggregate and systems for water cooling and pneumatic control of vacuum valves.

Beryllium for coating is contained in a beryllium oxide crucible mounted in an electrical resistance coil designed to ensure Be heating up to evaporation temperature in vacuum. The electrical heater is produced by FCN.

The appendages are placed in the upper zone of the vessel on a double trunk conic, rotating cupola.

A holster supporting the vessel contains all parts necessary for electrical, vacuum, cooling and pneumatic system control. For the equipment delivered to CNNC - 202 Plant, these parts have been procured from BOSCH. For the vacuum system, pumps and all other components the preference was for EDWARDS.

The view of the equipment is shown in Fig. 1

The operation for beryllium coating is similar for all components with the possibility to choose for the surface to be coated. Parts - bearing pads or spacers – are fixed in specific holders and mounted on the cupola. A stainless steel screen is placed around the cupola in order to protect the vessel from beryllium.

The assembly heater-crucible is not placed in the cupola center but at a specific lateral position ensuring the best condition for layer thickness uniformity. The cupola slowly rotates during the deposition process. The equipment operation is easy to be done with the operation panel in automatic or manually manner. The actual process phase is displayed on the operation panel.

The deposition of beryllium layer is obtained by evaporation. With a source of surface ds_1, the calculation of the beryllium layer thickness on the surface ds_2, may be obtained with Knudsen's cosine law.

$$t = \frac{m}{\pi\rho} \cdot \frac{\cos\phi \cos\theta}{r^2}$$

where:

t - represents beryllium layer thickness;
m - represents the metal mass in the crucible;
ρ - is the metal density;
Φ - is the angle between the normal to the metal surface and the vapor stream direction;
r - is the distance from the source to the surface ds_2;
θ - tilting of ds_2 with respect to the vapor stream direction;

The application of Knudsen' law is justified with the following conditions and assumptions:

- the small plane of the metal surface in the crucible may be considered of uniform temperature;
- the evaporation is carried out at a low pressure (5×10^{-5}mbar);
- the vapor intensity is so low that the effect of the collisions between the vapor molecules may be considered negligible;
- every vapor molecule striking the surface condenses on first impact.

In practice, a given film thickness of beryllium may be obtained by evaporating a weighed quantity of metal. However, some residue remains in the crucible.

A complete evaporation cycle including the cooling time lasts about less than three hours.

PROCESS REQUIREMENTS

As beryllium coating technology at FCN is not similar to that in place at Zircatec, adaptation was made in order to fit with subsequent Zircatec technology. Three special requirements were essential:

- beryllium thickness;
- thickness dispersion and,
- coating surface.

Few runs were necessary to check a range of operation conditions with different beryllium masses, m and to optimize the relative position of the crucible and cupola, Φ, r *and* θ. The final results were completely within ZPI specification.

Changing the coating surface is not a big technological problem but needs few adaptations of magazines and appropriate operating manner to cover all specified surfaces.

FINAL REMARKS

Two pieces of equipment for beryllium coating were designed and produced in Romania for CNNC - 202 Plant, according to ZPI specification.

A team from CNNC - 202 Plant visited FCN and became familiar with the equipment operation mode and all other details necessary to obtain high quality beryllium layer deposited on Bearing pads and spacers for CANDU–6 fuel.

AKNOWLEDGEMENTS

The authors wish to thank participants to the project and especially D. Newington from Zircatec for his pertinent suggestions for the equipment design and during the project.

REFERENCES

[1] R. SEJNOHA, M. WASH, A. C. GALERIU, "Qualification of FCN as a supplier of CANDU Power Reactor Fuel", CNS Third International Conference on CANDU fuel, Chalk River, Canada, 1992 October.

[2] C. A. GALERIU, G. ANDREI, A. BAILESCU, A. PASCU, L. ILIESCU, " Romanian – Canadian joint program for qualification of FCN as a CANDU fuel supplier" CNS Forth International Conference on CANDU fuel, Pembroke, Canada, 1995 October.

[3] A. C. GALERIU, A. PASCU, G. ANDREI, A. BAILESCU, " Five years of successful CANDU-6 fuel manufacturing in Romania", Sixth International Conference on CANDU fuel, Niagara, Canada, 1999 October.

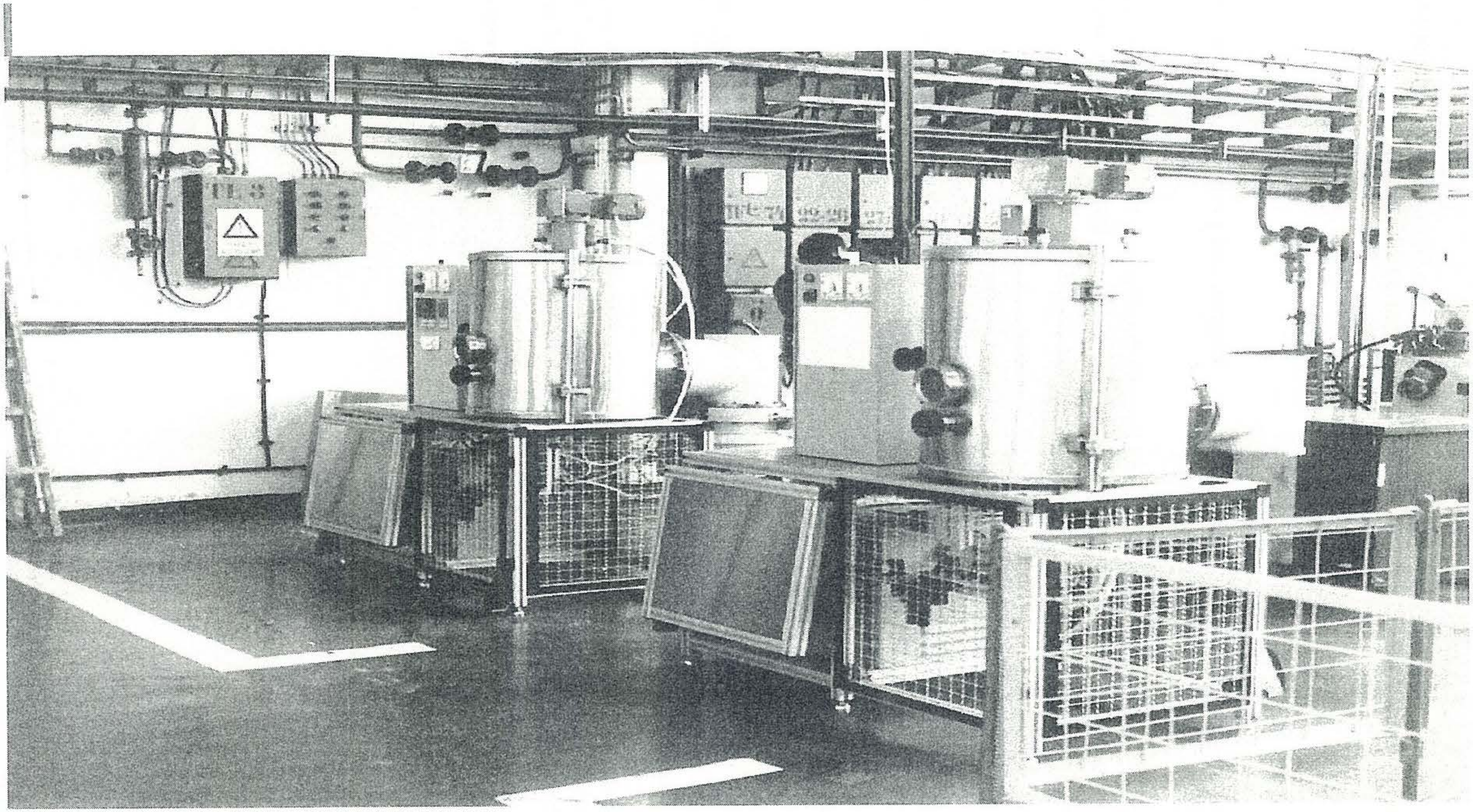

FIGURE 1 : BERYLLIUM COATING EQUIPMENT FOR CNNC – 202 PLANT