ROMANIAN NUCLEAR FUEL PROGRAM: PAST, PRESENT AND FUTURE

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ABSTRACT

The paper presents and comments the policy adopted in Romania for the production of CANDU-6 nuclear fuel before and after 1990.

In this paper the word "past" refers to the period before 1990 and "present" to the 1990-1997 period.

The CANDU-6 nuclear fuel manufacturing started in Romania in December 1983. Neither AECL nor any Canadian nuclear fuel manufacturer were involved in the Romanian industrial nuclear fuel production before 1990.

After January 1990, the new created Romanian Electricity Authority (RENEL) assumed the responsibility for the Romanian Nuclear Power Program.

It was RENEL's decision to stop, in June 1990, the nuclear fuel production at the Institute for Nuclear Power Reactors (IRNE) Pitesti. This decision was justified by the Canadian specialists team findings, revealed during a general, but well enough technically founded analysis performed at IRNE in the spring of 1990.

All fuel manufactured before June 1990 was quarantined as it was considered of suspect quality. By that time more than 31,000 fuel bundles had already been manufactured. This fuel was stored for subsequent assessment. The paper explains the reasons which provoked this decision.

The paper also presents the strategy adopted by RENEL after 1990 regarding the Romanian Nuclear Fuel Program.

After a complex program done by Romanian and Canadian partners, in November 1994, AECL issued a temporary certification for the Romanian nuclear fuel plant. During the demonstration manufacturing run, as an essential milestone for the qualification of the Romanian fuel supplier for CANDU-6 reactors, 202 fuel bundles were produced. Of these fuel bundles, 66

were part of the Cernavoda NGS Unit 1 first fuel load (the balance was supplied by Zircatec Precision Industries Inc. - ZPI).

The industrial nuclear fuel fabrication re-started in Romania in January 1995 under AECL's periodical monitoring.

In December 1995, AECL issued a permanent certificate, stating the Romanian nuclear fuel plant as a qualified and authorized CANDU-6 fuel supplier.

The re-loading of the Cernavoda NGS Unit 1 started in the middle of January 1997 with fuel produced by the Romanian fuel plant.

The quality evaluation of the "pre-1990" fuel started in April 1996 and was performed by the Nuclear Fuel Plant (FCN) Pitesti, under the supervision of the Nuclear Power Group (GEN) - a distinct department of RENEL.

The future prospect and trend of the Romanian Nuclear Fuel Program are also presented in this paper.

1. INTRODUCTION

Romania's option for the CANDU type reactors was made in the mid 60's and the first commercial discussions between the Romanian authorities and AECL began in the late 60's.

At that time, the main reasons for this choice of the Romanian authorities were related to the nuclear safety issues, the outstanding performance demonstrated by the CANDU type reactors and to the strategic advantage of the CANDU system that the nuclear fuel can be supplied locally. These reasons are still valid today.

In the 1970's Romania suffered severe floods and a serious earthquake and these facts combined with other economical shortages delayed the negotiations with the Canadian partners. In 1978 a contract for the CANDU-6 system license was signed between the Romanian authorities and AECL. From that moment on, Romania became the only Eastern and Central European country developing its nuclear power program based on the Western technology, and the first European country using the CANDU system. This situation is valid still today.

The paper presents the policy which governed the Romanian Nuclear Fuel Program before 1990. For the long term, this policy proved to be, inappropriate in several essential aspects, as it will be demonstrated below.

Several important decisions regarding the nuclear fuel production in Romania before 1990 did not prove to be well enough founded technically and economically while some proved even wrong. The political ambitions of the former Romanian nuclear authorities to develop the

CANDU-6 fuel manufacturing without any Canadian support, and the approval for the start of the large scale fuel production without any AECL involvement in the qualification of the Romanian nuclear fuel plant proved, on the long term, to be a mistake which generated significant economical losses.

After 1990, the new created Romanian Electricity Authority (RENEL) assumed the responsibility for the Nuclear Power Program. As for the Nuclear Fuel Program, RENEL elaborated a realistic strategy having three major objectives:

- The upgrading, with the Canadian support, of the new organized Nuclear Fuel Plant (FCN) as a distinct subsidiary of RENEL, in order to qualify the Romanian manufacturer as a recognized CANDU-6 nuclear fuel supplier according to the Canadian Z 299.2 standard;
- The re-start of the nuclear fuel production, after the qualification of the plant, in order to meet the Cernavoda NGS Unit 1 needs;
- The quality evaluation of the fuel produced before 1990 in order to decide upon the best possible technical and economical solution for its recovery.

The paper presents the way this policy was implemented and the results it led to.

The future prospects and trend of the Romanian Nuclear Fuel Program are also presented.

The paper ends with several general conclusions to be drawn out from the Romanian experience regarding the CANDU fuel manufacturing.

2. ROMANIAN NUCLEAR FUEL PROGRAM BEFORE 1990.

It is essential to notice that as far as the nuclear fuel is concerned, the contract signed in 1978 between the Romanian Authorities and AECL had only provided the transfer to the Romanian Party of an information package that included only the Technical Specifications applicable to the CANDU-6 fuel and the Fuel Design Manual for the Cernavoda station. The contract had no provisions regarding the fuel manufacturing technology transfer and no kind of co-operation with an experienced Canadian fuel manufacturer. At that time, the former Romanian nuclear authorities believed that it was possible to successfully develop the fuel manufacturing technology without any Canadian support. On long term, this approach proved to be a mistake which generated significant economical losses, in spite of the important and dedicated efforts made by the Romanian specialists involved in the nuclear fuel program. From the beginning, our specialists opposed the approach mentioned above, but the political ambition of the former Romanian nuclear authorities prevailed. As a result, in fact, Romania had to "re-invent" the CANDU fuel manufacturing technology and this goal had to be fulfilled under the conditions of a total isolation of our country ,imposed by political reasons, from the world nuclear fuel industry.

The history of the nuclear fuel fabrication in Romania before 1990 is described in detail in a paper presented previously at CANDU fuel conference [1]. The main activities related to the

development of the CANDU-6 nuclear fuel manufacturing were carried out at the former Institute for Nuclear Power Reactors (IRNE) in Pitesti.

With a few, but essential exceptions, the nuclear fuel fabrication in Romania went through a logical sequence of steps:

- Laboratory research and studies;
- Development of the our own fuel design;
- Development of a Quality Assurance (QA) system, including an Inspection and Testing Plan (ITP);
- Development of the technological processes for the nuclear fuel manufacturing;
- Designing and fabrication of the manufacturing equipment;
- Procurement from foreign suppliers of some special manufacturing equipment;
- Commissioning of a fuel pilot plant;
- Irradiation of fuel elements in research reactors, both in Romania and in foreign facilities (MZFR in Germany, BR2 in Belgium and NRU in Canada);
- Out of pile tests for fuel bundles produced in the pilot plant, tests performed in the high pressure and temperature loop built at IRNE.

The results obtained were encouraging. No abnormal results were recorded during this (though limited) testing program, both in irradiation and in out of pile tests.

To fulfill these steps, mentioned above, many financial and technical efforts were made at IRNE Pitesti. It is enough to mention here the procurement of a 14 MW Material Testing Reactor (TRIGA - type) - in operation from 1979, hot cells facilities - in operation from 1984, high pressure and temperature loop and analysis and control laboratories.

Regarding the activities described above, the following remarks should be emphasized:

- The irradiation tests consisted mainly in the well known type-tests for CANDU fuel (overpower test and power ramp test) for fuel elements. This kind of tests are aiming, mainly, at checking the fuel element design and cannot in any case be considered as a substitute for the qualification of the fuel manufacturing plant;
- No fuel bundles were tested in power reactors;
- The compatibility testing program on the fuelling machine head was not performed before 1990.

It is evident that looking back at the chain of the activities performed in order to prepare the large scale fuel production, the following links were missing:

- The fuel plant was not qualified by AECL, the design authority for CANDU system;
- The lack of co-operation with an experienced Canadian nuclear fuel manufacturer;
- The limited (if any) feed-back in the fuel production coming from the fuel behavior showed during irradiation tests.

In spite of this evidence, the former Romanian nuclear authority (the State Committee for Nuclear Energy - abolished in January 1990) decided, without any involvement neither by AECL nor by an experienced Canadian manufacturer, to approve the start of the industrial production for

CANDU-6 nuclear fuel at IRNE Pitesti. On this basis, which later did not prove to be enough founded, the industrial production of CANDU-6 fuel began at IRNE Pitesti in December 1983. Before June 1990, intensive production of CANDU-6 fuel was maintained (see Table 1). It should be noticed that the fuel production dynamics had no logical linkage with the real status of the progress in the construction of the power reactors at the Cernavoda site.

Looking back in the past, we can conclude that the policy followed in Romania regarding the Nuclear Fuel Program was not appropriate and not well enough founded technically and economically.

However, we should emphasize that in spite of this policy, impressive results were obtained and, besides, the Nuclear Fuel Program developed in Romania before 1990 was an excellent frame to grow an important number of specialists in the CANDU fuel nuclear technology. These positive aspects paid back, to a great extent, the efforts made in Romania before 1990.

Unfortunately, as it will be present below (and in detail analyzed in another paper at this CANDU conference [2], the quality of the fuel produced before June 1990 (more than 31,000 fuel bundles) was not good enough concerning the quality and that is why this fuel cannot be used as such in reactor.

3. ROMANIAN NUCLEAR FUEL PROGRAM AFTER 1990.

In January 1990 the former Romanian nuclear authority - the State Committee for Nuclear Energy was abolished and the new created Romanian Electricity Authority (RENEL) assumed the responsibility for all the energy national program (electricity and heat production). The Nuclear Power Group (GEN), as a department of RENEL, assumed the responsibility for the Romanian Nuclear Power Program.

Regarding the Nuclear Fuel Program, the first action decided by GEN was to request that AECL perform an evaluation of the fuel fabrication at the Romanian plant. The approach was focused on the technology, quality assurance system and the quality of the fuel produced before 1990. The evaluation was performed by AECL and Zircatec Precision Industries Inc.(ZPI). The findings of the Canadian specialists were presented in detail in [3], [4].

We present here the main conclusions of the Canadian specialists after their assessment performed at the Romanian fuel plant:

- Romanian fuel plant achieved impressive progress in developing the facility, training personnel and implementing manufacturing processes and inspection methods. The review found many positive features which indicate that some parts of the fuel are of good quality [3], [4];
- There were several negative findings:

* The Quality Assurance (QA) system in use at the Romanian plant was not adequate for nuclear fuel manufacturing [4];

* In Canada, Product Specifications combine the requirements of the Technical Specifications with essential information on manufacturing processes and quality assurance, and specify the levels of conformance with Technical Specifications requirements. At the Romanian fuel plant, Product Specifications did not exist before 1990 [3];
* Conformance to the stated requirements was unacceptable, and in one important case (fuel element closure welds) the requirement was inappropriate. This leads to low quality of the fuel;
* The manufacturing processes and their control were inadequate in the assemble fuel element operation, and suspect in the braze operation;

- As regarding the fuel produced before 1990 the Canadian experts concluded that the fuel already fabricated should be considered as being of suspect quality for the in reactor use [3], [4], [5].

On this basis and after a realistic assessment of the situation, it was the RENEL-GEN's decision to stop, in June 1990, the nuclear fuel production at IRNE Pitesti. All the nuclear fuel manufactured before June 1990 was quarantined as it was suspect for use in power reactor. As mentioned before, more than 31,000 fuel bundles had already been manufactured at that time. The already fabricated nuclear fuel was stored at Pitesti under International Atomic Energy Agency (IAEA) safeguards.

The Nuclear Power Group elaborated a strategy to be followed for the Romanian Nuclear Fuel Program. Three major objectives have been decided:

- The upgrading, with Canadian support, of the Romanian nuclear fuel plant in order to qualify it as a recognized CANDU-6 fuel supplier according to the Canadian Z 299.2 standard;
- The re-start of the nuclear fuel production of the plant, in order to meet, on a realistic basis, the Cernavoda NGS Unit 1 needs;
- The evaluation of the "pre-1990" fuel quality, aiming at identifying the best possible way for its recovery, both from technical and economical point of view.

To achieve these goals it was essential that, in the new contract signed in August 1991 between RENEL and AECL - Ansaldo Consortium (AAC) for the completion of the Cernavoda NGS Unit 1, all the necessary conditions were assured, including the nuclear fuel program. This contract included the assignment for AAC to provide assistance for the qualification of the Romanian nuclear fuel manufacturer.

Since February 1992 the nuclear fuel manufacturing has been organized as an independent RENEL's subsidiary, named Nuclear Fuel Plant (FCN).

Arrangements between GEN and AAC ended up in November 1992 with a contract for the qualification of FCN as a recognized CANDU-6 fuel supplier, giving to AECL the coordinating role. ZPI was selected to provide technical assistance and to supply equipment for several processes. The qualification program started in December 1993, after the Export Permit issuing by the Canadian Government.

The qualification of the plant was completed in July 1994 and a demonstration run was performed during October 1994 by producing 202 CANDU-6 fuel bundles and 66 of these fuel bundles were part of the Cernavoda NGS Unit 1 first fuel load (the balance was supplied from Canada by ZPI).

In November 1994, AECL issued a temporary certification for FCN.

The philosophy and detailed steps of the FCN qualification are described in two papers presented previously at CANDU fuel conference [6],[7].

Industrial nuclear fuel production was resumed in January 1995 under periodical AECL's monitoring.

In December 1995, AECL issued a permanent certificate, stating FCN as a qualified and authorized CANDU-6 nuclear fuel supplier. The plant capacity is of 23 bundles per day.

The evolution of the FCN fuel bundles production after the plant qualification is presented in the Table 2.

The Cernavoda NGS Unit 1 started its commercial operation on 1996 December 2. The reloading of the reactor started in the middle of January 1997 with fuel produced by FCN after 1995. Till the end of July 1997, 2524 bundles produced by FCN were already loaded in the Cernavoda NGS Unit 1 without any problem (no defect of the Romanian fuel was detected till the end of July 1997).

On the basis of the new status of the plant, Nuclear Power Group (GEN) requested FCN to perform detailed evaluation of the stock fuel quality. Once a very comprehensive feasibility study performed by the fuel plant specialists was accepted, GEN decided that this evaluation program should be implemented by FCN. The evaluation program for the assessment of the stock fuel quality started in April 1996.

The strategy adopted by FCN for the quality evaluation of the fuel produced before 1990, the results obtained and the best possible technical and economical recovery solutions are presented in detail in another paper at this CANDU conference [2].

In December 1996, RENEL-GEN requested that AECL, as design authority for the CANDU system, perform a qualified appraisal of the evaluation program developed and implemented by FCN. The task was performed by Dr.Roman Sejnoha and the detailed findings, conclusions and recommendations are summarized in [8]. The main conclusions in [8] are that the evaluation strategy was well conceived, the effective work was well done and the data were collected and recorded in a proper manner. This assessment report also confirms the FCN solution for the best possible recovery of the stock fuel (already applied by now).

The results obtained by FCN during the quality evaluation of the stock fuel show, without any doubt, that this fuel is not suitable for in reactor use. Only the uranium contained in the stock fuel can be recovered either as pellets, as they are, or by recycling the unacceptable pellets.

By performing the complex program for the quality evaluation of the stock fuel, in a very satisfactory manner, it was demonstrated that the excellent co-operation with AECL and Zircatec, brought FCN capability to a level beyond the manufacturing activities. It should also be emphasized that the quality evaluation of the fuel produced before June 1990 was performed in parallel with the normal fuel manufacturing activity.

4. THE FUTURE OF THE NUCLEAR FUEL PROGRAM IN ROMANIA

Today, Romania has a fully integrated nuclear supply industry for its CANDU-6 type reactor. The nuclear fuel production is an essential activity for the Romanian Nuclear Power Program.

After the FCN qualification was done with AECL and ZPI support, the nuclear fuel production at the Romanian plant was very satisfactory. High quality CANDU-6 fuel was produced, appropriate relationships between the fuel plant, its suppliers and the Customer (Cernavoda NGS Unit 1) were established and the FCN personnel gained more experience and confidence in their capability.

For the future the following objectives are essential for the nuclear fuel manufacturing:

- Preserve and improve the actual FCN capability to produce high quality fuel. This means not only to keep the plant equipment in good shape or to procure more competitive equipment where necessary, but also to preserve and increase the personnel skill and responsibility that is laid upon them;
- Maintain a permanent contact with AECL, as the design authority, and with experienced CANDU-6 fuel manufacturers from abroad in order to be ready at any time to implement all the improvements which will certainly appear in the future;
- Decrease the fuel bundle cost especially by looking for better economical contracts with the fuel plant suppliers of UO_2, Zy-4 tubes and Zy-4 sheets and rods. Technology improvements, which can be developed at FCN, could also contribute to achieve this goal;
- Consider and analyze the possibilities and the advantages for both parties to establish a joint-venture with a foreign experienced CANDU-6 fuel manufacturer. This could help to increase the FCN position especially in the world CANDU-6 market;
- On the short term, four to five years, FCN has to complete the recovery of the fuel produced before June 1990, on the basis of the solutions established after the quality evaluation of this fuel, evaluation which now is, practically, completed.

The nuclear fuel production at FCN should be in a strict correlation with the Romanian market demand (and possible with the international market) in order to avoid the old policy of producing fuel on stock.

With respect to the Romanian nuclear fuel market it is easy to predict the future needs. The new Romanian political authorities, in place after the November 1996 election, issued, at the beginning of this year, a Governmental decision defining the completion of the Cernavoda NGS Unit 2 as a national priority for the next five years. As a result, for this period of time, FCN has two major tasks:

- Meet the nuclear fuel needs of the Cernavoda NGS Unit 1;
- Prepare the increase of the production capacity in order to meet, starting not later than 2001, the needs for two CANDU-6 Units.

Now, RENEL is subject to a restructuring process, but regardless of the final decisions about the way this will be pursued, the future of the FCN is solid and safe. It is sure that in the future, the status of FCN will consolidate and the nuclear fuel plant will gain more flexibility and independence.

5. CONCLUSIONS

Romania opted for the CANDU system in the mid 60's and this option proved, on long term, to be an excellent choice.

In the 80's the Governmental program for nuclear energy was quite impressive and too ambitious, in some aspects even unrealistic. It included nuclear fuel fabrication for all five CANDU-6 reactors to be constructed at Cernavoda. However, the bilateral arrangements for the nuclear fuel manufacturing technology transfer from Canada to Romania were inconsistent with the Romanian objectives. As it is well known, the nuclear fuel manufacturing technology was developed before 1990 without any Canadian support.

In most respects, the manufacturing technology reached before 1990 an impressive level. However, as presented in this paper, several essential aspects related to the CANDU-6 fuel manufacturing were not properly solved.

The decision to start the large scale nuclear fuel fabrication in December1983 without any involvement neither by AECL nor by an experienced Canadian fuel manufacturer, proved to be a mistake which generated significant economical losses.

The nuclear fuel production in Romania before June 1990 had no logical linkage with the real status for the construction progress of the power reactors at the Cernavoda site.

Even if the policy of the Romanian Nuclear Fuel Program before 1990 was inappropriate, a remarkable experience was gained and this positive experience, paid back, to a great extent, after 1990. It is worth mentioning here that because of this experience gained before 1990, the cost paid for the qualification, by AECL and Zircatec, of FCN as a recognized CANDU-6 fuel supplier, was rather modicum.

After 1990, the new Romanian nuclear power authority, RENEL-GEN, elaborated a realistic Nuclear Fuel Program. This program went through the Romanian nuclear fuel plant qualification with the Canadian (AECL and ZPI) support, re-starting in January 1995 of the industrial nuclear fuel production, quality evaluation of the fuel produced before 1990 and starting of the recovery of this fuel.

This new policy already produced good results.

FCN is now a qualified CANDU-6 fuel supplier and by the end of July 1997 about 55% from the fuel core of the Cernavoda NGS Unit 1 is coming from FCN production.

The future of the Romanian Nuclear Fuel Program is bright and has solid basis.

As a general conclusion we can stress that it is obvious that without a political support no national nuclear program is possible, but too much political involvement in the technical aspects is not beneficial at all.

It is not a wise policy to develop all the things using only your own efforts without any international co-operation.

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TABLE 1. EVOLUTION OF THE FUEL BUNDLES PRODUCTION BEFORE JUNE 1990

MONTH	YEAR							
	1983	1984	1985	1986	1987	1988	1989	1990
January	10	48	133	262	551	417	287[1]	400
Fbruary	2	56	42	441	531	583	507	210
March	0	96	260	393	375	700	766	410
April	0	80	32	450	675	442	720	450
May	0	120	106	465	534	585	843	456
June	0	98	290	389	609	800	605	48
July	0	112	242	355	565	650	122	0
August	0	188	242	402	560	607	660	0
September	0	206	240	404	561	600	1033	0
October	0	100	253	200	597	509	809	0
November	5	176	205	347	569	208	852	0
December	65	325	464	405	485	970	134	0
Total production/year	82	1605	2509	4513	6612	7071	7338	1974
Total in stock/year	65	1577	2505	4509	6605	7071	7338	1974
Total production = 31,704 fuel bundles								
Total production in stock = 31,644 fuel bundles[2]								

[1] Depleted fuel bundles

[2] The diference between the total fabricated fuel and the stocked fuel bundles was used for out of pile tests

TABLE 2. EVOLUTION OF THE FCN FUEL BUNDLES PRODUCTION AFTER PLANT QUALIFICATION

YEAR	QUARTER	PRODUCTION	CUMULATIVE PRODUCTION
1994	4	202	202
1995	1	230	432
	2	316	748
	3	601	1349
	4	531	1880
1996	1	257	2137
	2	775	2912
	3	90	3002
	4	453	3455
1997	1	1088	4543
	2	1604	6147
	3[1]	1236	7383
	4[1]	1470	8853

[1] Planned