QUALITY EVALUATION OF THE NUCLEAR FUEL MANUFACTURED IN ROMANIA BEFORE 1990

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ABSTRACT

Nuclear fuel fabricated in Romania before June 1990 was stored and was not licensed for the use in reactor. A preliminary appraisal performed by AECL and Zircatec experts in 1990, considered this fuel as being of suspect quality.

Taking into consideration that Nuclear Fuel Plant was qualified to produce CANDU-6 fuel, only after 1990, RENEL-GEN authorized FCN to evaluate the actual quality of the stock fuel, in 1996.

A documented evaluation program was developed and implemented. Stock production of each year was considered as one fuel bundle lot. Quality verification was done on statistical basis. Random sampling was applied, with the condition that each production week was represented in the sample.

The results show that the fuel quality is not acceptable for in-reactor use. Recovery solutions for the stock fuel were established and already applied. An independent review of the program, results and recovery solutions, made by AECL confirmed the consistency of the work performed by FCN for stock fuel quality evaluation.

1. INTRODUCTION

CANDU-6 nuclear fuel fabrication started in Romania in 1983. Preparatory activities were performed in a logical sequence, including both in pile and out of pile tests on fuel similar to standard power reactor fuel [1].

The start of the production was decided at that time, by the former Romanian authority without any involvement neither by AECL nor by an experienced Canadian fuel manufacturer. Before June 1990, more than 31,000 Candu-6 fuel bundles were fabricated and stored for subsequent use.

In 1990, RENEL - the new authority for the Romanian CANDU reactor program, requested 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.

The evaluation performed by AECL and Zircatec Precision Industries Inc., concluded that the fuel already fabricated should be considered as being of suspect quality for the in-reactor use. As a result of this analysis, fabrication was stopped in June 1990, and the fuel manufactured up to that date quarantined.

AECL - ANSALDO Consortium, the partner for the Cernavoda Unit 1 Project Management Contract, including the first stage of reactor operation, decided not to use the fuel manufactured before June 1990.

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

Nuclear Fuel Plant was upgraded and qualified in the frame of a contract between RENEL, AECL and Zircatec. Industrial production was resumed in January 1995. Plant qualification was described in two papers, presented previously at CANDU fuel conferences [2], [3].

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.

The paper describes the program strategy, main steps of the evaluation, and the way how the results are used for the best possible recovery of the stock fuel.

So far, the evaluation has already been concluded for the production years 1983, 1984, 1985, 1986, and this activity has continued with the depleted fuel, fabricated in January 1989.

The paper also describes the fuel recovery procedure adopted.

2. EVALUATION PROGRAM

Starting with the findings of the first exploration of the stock fuel, done by an AECL-Zircatec team, in 1990, FCN continued to evaluate the possibility to obtain the best achievable view regarding the effective quality of the stock fuel.

Two important conclusions were drawn after the evaluation done by the Canadian experts :

- A number of characteristics, especially related to the assembling processes, ask for a special attention. It is the case of the fuel element end cap welds, end plate welds torque resistance and braze joints quality;
- Pellet fabrication was found to be acceptable, pellets being found having an acceptable quality. This fact was later confirmed during the plant qualification, the pellet fabrication practically remaining unchanged.

Having in view the volume of stock production, RENEL-GEN asked for a careful quality evaluation, aiming to identify the best possible recovery solution for the fuel produced before June 1990.

A very comprehensive feasibility study was prepared by FCN, with the objective to enable GEN to take a well founded, technical and economical decision, regarding the strategy to be followed for the fuel stock recovery. This documentation included all imaginable situations regarding the quality status for fuel bundles and components, and for each situation a technical and economical assessment was made.

Once the feasibility of quality evaluation of the stock fuel was accepted, GEN decided that this program should be implemented by FCN. The final details of the strategy were established by FCN in February 1996 . The evaluation strategy was described in an Evaluation Plan approved by GEN.

Even if the first appraisal made by AECL-Zircatec team, revealed only a number of essential deficiencies, FCN made provisions in the evaluation plan for the thoroughly verification of all quality features listed in Appendix E of TS-XX-37000-4.

The documentation package prepared for this program includes:
- Comparison Between CANDU-6 Fuel Design Documents Used for Stock Fuel and for Actual FCN Manufacturing Versus AECL Design Requirements, ACPC-01;
- Evaluation Strategy of the Nuclear Fuel Manufactured in 1983-1990, ECNS-01;
- Stock Fuel Evaluation Plan, PE-001;
- Inspection and Test Plan for Stock Fuel, PCCVI-E;
- Evaluation Verification Instructions:
  - Evaluation of Pellets, IC-05-E;
  - Evaluation of Fuel Elements, IC-06-E;
  - Evaluation of Fuel Bundles, IC-07-E.

Some specific procedures were necessary to be elaborated in order to ensure proper material control during this activity.

In designing the evaluation plan, of great help was the fact that the original fabrication used an acceptable system for material identification and traceability. Quality records were also maintained in a good manner.

The main problem was how to define the lot volume for verification. For the assembling processes, it was evident from the beginning that there was not enough support to delineate homogenous fabrication lots. We found that the most reasonable way to obtain a realistic view of the quality of the fuel stock, was to sample representative items from the entire period of production.

The evaluation is based on statistical methods. Each year of manufacturing, 1983 to 1990, is treated as one lot and evaluated separately. The size of fuel bundle samples taken for verification, was generated according to the MIL-STD 105D, Nc=II (See Table 1). Samples for the parts, obviously resulted in the same way, depending of the total part volume, being higher than bundle sample. Sample items were distributed randomly along the year, ensuring investigation of fuel bundles from each week, weighed to the week production.

As a consequence of the verification standard, all inspection data were treated as attributes.

Evaluation criteria were established to be similar to the actual acceptance criteria for the current production. This was possible due to the fact that the design of the stock fuel is similar to the present FCN design.

The verification plan was documented in a manner similar to an Inspection and Test Plan (ITP). This plan defined the sample sizes for each characteristic and specific acceptance criteria.

Except for visual and dimensional features, the verification was based on destructive inspection. Verification was performed using the methods implemented at FCN during the Fuel Plant qualification program. The sequence for evaluation is presented in Figure 1.

The activity was governed by the quality assurance system in operation for current CANDU-6 fuel production, in place now at FCN.

3. RESULTS

The evaluation results for 1983-1986 and the 1989 depleted fuel, are collected in separate Quality Evaluation Reports (RCS-83, RCS-84, RCS-85, RCS-86 and RCS-89S) and Evaluation History Dockets.

The situation is very similar regarding the fuel quality of the evaluated lots. Some variation exists from lot to lot, but the results show the same kind of deficiencies. There is no trend of improvement from year to year.

The most important aspects found to be unacceptable are grouped in the following categories:

- Fuel bundle dimensions out of specification, the most important being those affecting the compatibility with the fueling system;
- Fuel assembling welds with a high spread in torque resistance;
- Incomplete fuel element closure welds. Frequency of nonconforming welds is so high that even for an AQL ~ 2,5 the lot should be rejected. This fact is caused by the geometry of the weld interface and inadequate acceptance criteria with respect to weld integrity above the sheath;
- Sheaths with graphite layer thickness out of specification;
- Hydrogen content in fuel elements presenting values much higher than the specified value. We found unacceptable high hydrogen content both by extraction at 200°C (hydrogen in moisture), and by extraction at 550°C (hydrogen in the graphite layer).As a consequence, it is obvious that in a significant number of samples, the total hydrogen content was higher than the specified value;

- Poor braze joint quality, especially for marginal voids and grain size in the heat affected zone. The number of reject samples for metallography is high and the equivalent AQL is not acceptable.

Regarding the pellet quality, for each pellet lot, an investigation of initial records was made, including UO_2 powder. We compared the original data against the acceptance criteria. There are few cases with powder lots presenting small deviations from the chemical composition but the final pellet chemical composition was found to be in the specification limits.

We also took into consideration the new provision for powder chemical composition, especially for phosphorus according to last revision of the specification for UO_2 powder, issued by AECL after 1990. The intention was to obtain relevant data to ensure recovery of the material in accordance with the actual limits.

Discharged UO_2 pellets have been found in a good condition. Roughly, the verification scheme permitted us to re-inspect about one third of pellet lots. The results obtained showed that recovery of a big part of the lots was possible in the form of pellets. Pellet geometry is similar to the actual design.

Chemical composition of the pellets is according to the applicable specification. Microstructure was acceptable. Density measurements for re-inspection show that about 70% of pellet lots are fully in specification limits, the balance presenting minor deviations.

4. RECOVERY SOLUTIONS

In establishing the recovery solutions, the following information proved to be essential:

- Bundle dimensions and end plate welds torque resistance were found to be not acceptable;
- Element end cap welds had a poor quality;
- Hydrogen content in elements was over the specified limits, this representing in fact, the key reason for the adopted recovery solution.

As a result, the best recovery solution was decided to be the dismantling of all the stock fuel bundles and recovery of all acceptable pellets. Unacceptable pellets are recovered by recycling to powder and fabrication of new pellets. The fabrication of the new fuel bundles with recovered pellets is governed by specific manufacturing, inspection and test plans. The recovery flow sheet is presented in Fig.2.

Both solutions were already applied. New fabricated fuel bundles, containing accepted pellets after dismantling, started to be loaded in Cernavoda Unit 1 reactor starting with the middle of May 1997.

Parts of the components could also be recovered, e.g., sheaths. To do this, two characteristics shall be verified : braze quality and graphite coating properties.

It is normal to look for a 100% nondestructive inspection of braze quality, due to the process features. For graphite coating, it is possible to apply a statistical verification.

In any case, the use of the dismantled sheaths needs a special design to compensate the shorter lengths. Such a new design raises new problems, e.g., reactor physics and reactor operation assessments.

The recovery solutions adopted by FCN for the stock fuel have been accepted by RENEL-GEN and the Customer.

5. PROGRAM ASSESSMENT

In December 1996, after the completion of the fuel quality evaluation for the lots from 1983, 1984 and 1985, 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. Verification at that moment was practically completed for all characteristics, except for the hydrogen content in the 1985 fuel element lot.

The task was performed by Dr. Roman Sejnoha, AECL Fuel Design Branch, who was deeply involved in the qualification program of the Romanian fuel plant.

The detailed findings, conclusions and recommendations made by Dr. Roman Sejnoha are summarized in a report [4], distributed to RENEL, FCN and AECL.

The main conclusions in [4] 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 solutions for the best possible recovery of the stock fuel.

We appreciate that the successful completion of this quality evaluation program, proved that FCN, once qualified for CANDU-6 fuel manufacturing, is also able to conceive and implement projects having such a complex objective. This represents a great satisfaction for the FCN personnel who was deeply dedicated in the fuel plant qualification program. By performing in a very satisfactory manner this evaluation program they demonstrated that the cooperation with AECL and Zircatec brought FCN capability to a level beyond the manufacturing activities.

A great benefit of the successful completion of this evaluation program is the increased confidence of the Customer (Cernavoda Unit 1) with respect to FCN's capability to manage activities related to nuclear fuel.

6. CONCLUSIONS

The special program used for quality evaluation of the CANDU-6 stock fuel, produced before June 1990, was well documented and conducted, and it should be emphasized that this activity was performed in parallel with the normal fuel manufacturing.

FCN was able to put in practice and complete the work for the lots 1983-1986 and the depleted fuel lot, produced in January 1989, in less than one year.

The results obtained show, without any doubt, that stock fuel was not suitable for in reactor use.

It is very probable that for the remaining lots, no additional verification will be requested by RENEL-GEN but a simpler verification plan could be applied, e.g., only hydrogen content in the fuel elements can be enough to draw the decision for recovery. This was also suggested by Dr. Roman Sejnoha.

Recovery solutions were adopted depending on the effective quality. Pellets were recovered to a higher extent after the re-verification as required by the actual ITP. Rejected pellet lots or sorted pellets were recycled to powder.

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REFERECES

1. CONSTANTIN A. GALERIU, AXENTE PASCU, "Nuclear Fuel Fabrication in Romania", Third International Conference on CANDU Fuel, Chalk River, Canada, 1992 October 4-8.

2. ROMAN SEJNOHA, MARTIN WASH (Canada), CONSTANTIN A. GALERIU (Romania), "Qualification of FCN as a Supplier of CANDU Power Reactor Fuel", Third International Conference on CANDU Fuel, Chalk River, Canada, 1992 October 4-8.

3. CONSTANTIN A. GALERIU, GHEORGHE ANDREI, ANA BAILESCU, AXENTE PASCU, MIHAIL LIVIU ILIESCU, " Romanian-Canadian Joint Program for Qualification of FCN as a CANDU Fuel Supplier", Fourth International Conference on CANDU Fuel, Pembroke, 1995 October 1-4.

4. ROMAN SEJNOHA, "Recovery of CANDU-6 Fuel Manufactured before 1991 and Stored at FCN", 1997 January 23.

TABLE 1. STOCK FUEL - LOTS AND SAMPLES

LOT	LOT SIZE (BUNDLES)	SAMPLE SIZE (BUNDLES)
1983	65	65
1984	1,577	80
1985	2,505	80
1986	4,509	315
1987	6,605	315
1988	7,071	315
1989	7,338	315
1990	1,974	80
TOTAL	31,644	1,565

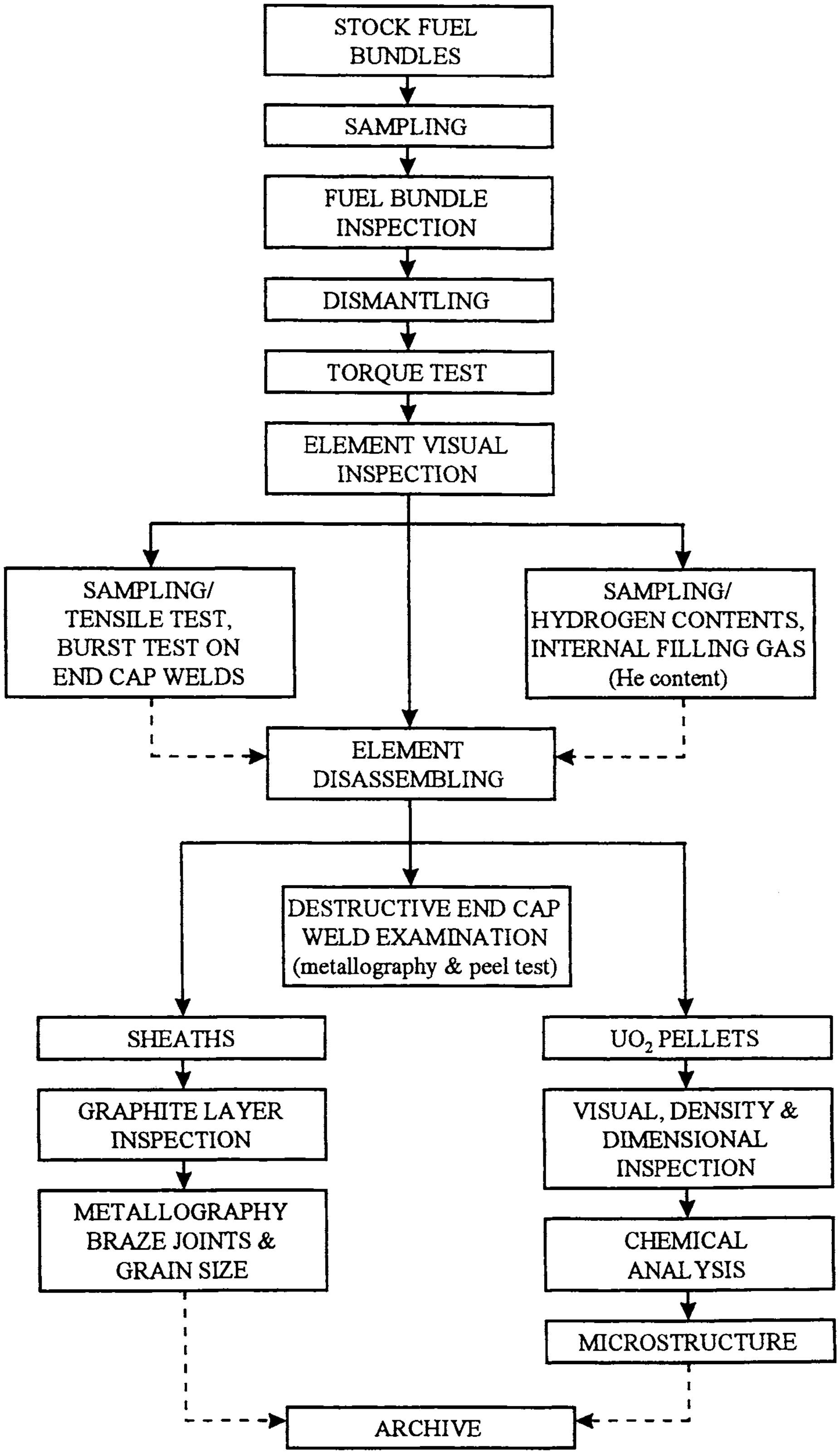

Fig. 1. QUALITY EVALUATION OF STOCK FUEL PRODUCED IN ROMANIA BEFORE 1990

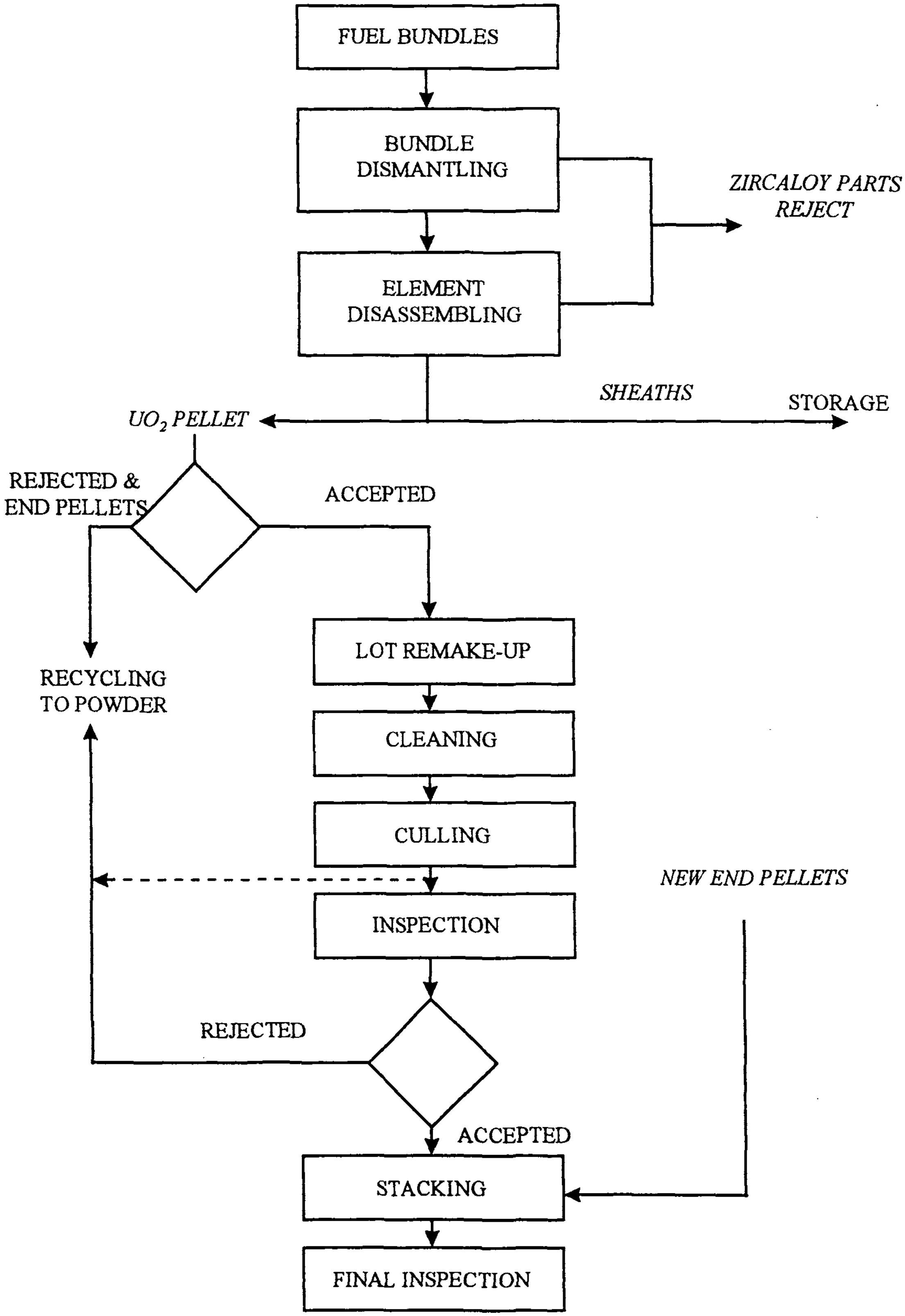

Fig. 2. RECOVERY OF UO_2 PELLETS - ROMANIAN FUEL STOCK MANUFACTURED BEFORE 1990