LEU FUEL FABRICATION PROGRAM FOR THE RECH-1 REACTOR. STATUS REPORT

J.C. CHAVEZ, M. BARRERA, O. JIMENEZ, J. LISBOA, J. MARIN

Unidad de Combustibles, Departamento de Materiales Nucleares.
Comision Chilena de Energía Nuclear, Amunategui 95, Santiago 6500687- Chile

ABSTRACT

In 1995 a 50 LEU U_3Si_2 fuel elements fabrication program for the RECH-1 research reactor was established at the Comision Chilena de Energia Nuclear, CCHEN. After a fabrication process qualification stage, in 1998, four elements were early delivered to the reactor in order to start an irradiation qualification stage. The irradiation has reached an estimated 10% burn-up and no fabrication problems have been detected up to this burn-up level. During 1999 and up to the first quarter of 2000, 19 fuel elements were produced and 7 fuel elements are expected for the end of 2000.

This report presents an updated summary of the main results obtained in this fuel fabrication program. A summary of other activities generated by this program, such as in core follow-up of the four leader fuel elements, ISO 9001 implementation for the fabrication process and a fabrication and qualification optimization planning, is also presented here.

1. Introduction

The RECH-1 reactor, a 5 MW open pool reactor, has been in operation since 1974, and in 1985 was converted from HEU (80% enrichment) to MEU (45% enrichment) fuel. In 1994 the decision for the MEU to LEU conversion was taken by the authorities of the Chilean Nuclear Energy Commission (CCHEN). In 1995 a 50 LEU U_3Si_2-Al fuel elements fabrication program for this reactor started with the fuel fabrication plant implementation and licensing stage. In 1998, the fabrication process was submitted to a qualification stage that resulted in four fuel elements. They were early introduced in the reactor - two in December 1998 and two in July 1999 – as "leader" LEU fuel elements, in order to anticipate the behavior and performance of the standard fuel elements.

During 1999 and 2000 the standard fuel fabrication has been in progress, resulting in 19 finished fuel elements by April 2000. Seven fuel elements are expected by December 2000. This report presents a summary of the fabrication activities developed in this endeavor and a summary of other activities that this program has generated: irradiation follow up of the leader elements, implementation of a quality system management based on ISO 9001, and improvement planning for the fabrication process.

2. The RECH-1 fuel element

The main design restriction imposed by the reactor operator was to maintain the original HEU fuel geometry in the LEU fuel element. This was required in order to maintain and match the cycle length of the HEU fuel and its thermal-hydraulic operational parameters. U_3Si_2 was a natural choice considering the 3.4 MgU/m^3 density required in the LEU fuel core and its irradiation behavior [1]. The specification for the standard LEU RECH-1 fuel element was

obtained from the fuel development stage results and validated during the qualification stage [2]. The main specified nominal values are:

- U^{235} content, external plates : 7.16g +/- 2%
- U^{235} content, internal plates : 14.32g +/- 2%
- U^{235} content per fuel element : 214.8g +/- 2%
- U per fuel element, total : 1087.2g +/- 2%
- U density, meat : 3.4 MgU/m^3
- U homogeneity, external plates : 102.81 mgU/cm^2 +/-20%
- U homogeneity, internal plates : 205.63 mgU/cm^2 +/-20%
- Fuel plate core length : 586.0 mm (average)
- Fuel plate core width : 60.15 mm (+0.55/-0.45 mm)
- Fuel plate core thickness : 0.61 +/- 0.02 mm
- Cladding thickness : 0.46 +/- 0.03 mm
- Cooling channels width (gap) : 3.17 mm (2.92 mm min.)

The RECH-1 LEU fuel element has 16 flat fuel plates. The fuel core density is 1,7 MgU/m^3 for the 2 external plates and 3.4 MgU/m^3 for the 14 internal fuel plates. These 16 fuel plates are attached to two side plates, by roll swaging, resulting in the fuel box. The end pieces (nozzle and filter box) are attached to the fuel element box by welding. All the structural components of the fuel elements are 6061 Aluminum. A general view of the fuel element is presented in Fig. 1.

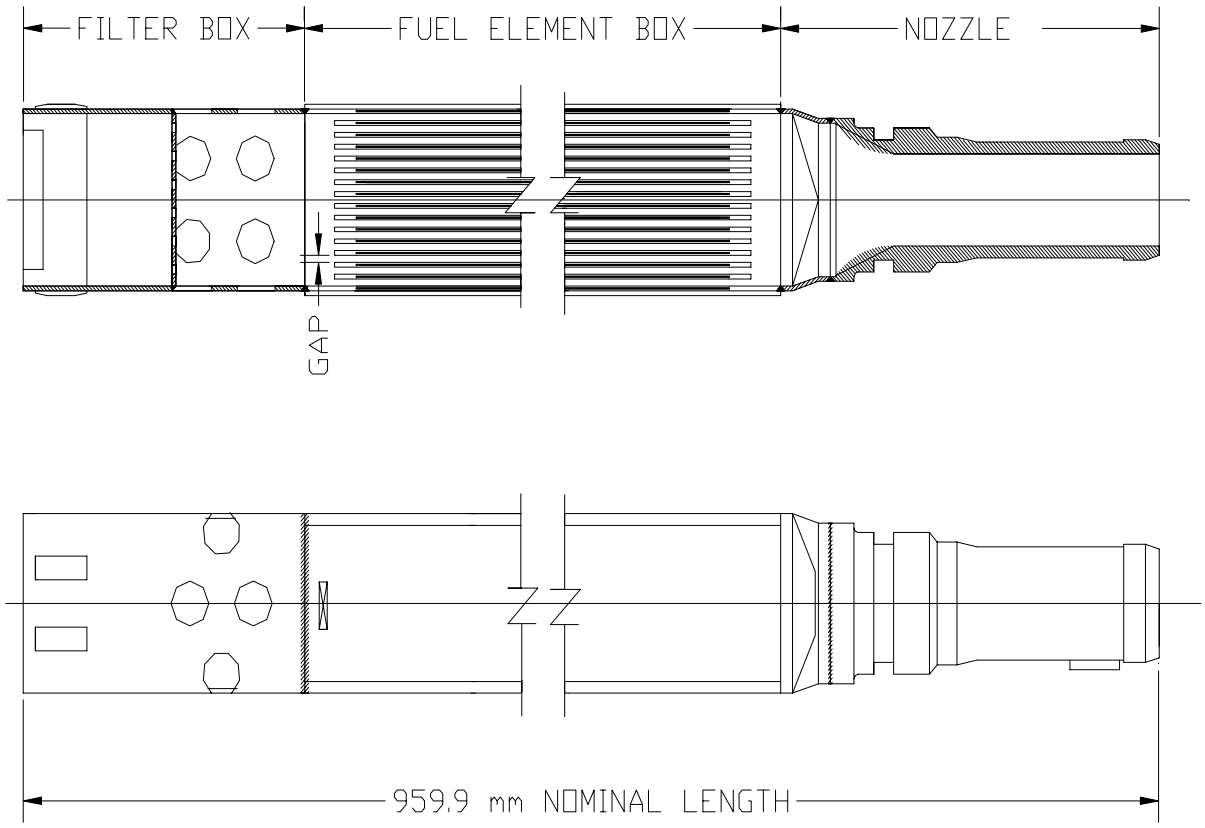

Fig. 1 General view of the RECH-1 Fuel Element.

3. LEU Fuel fabrication program

The LEU fuel fabrication program has been developed in the following stages:

- Development stage.
  In this stage, from 1995 up to 1997, the implementation of the Fuel Fabrication Plant was completed, LEU Uranium and structural materials were acquired, and the fuel element fabrication specifications were developed, tested under fabrication conditions and finally submitted to the approval of the reactor operator [3]. In parallel to these activities, the licensing of the proposed fabrication process was in progress and ended in March 1998.

- Fuel fabrication qualification stage.
  In 1998, the LEU U_3Si_2-Al fuel fabrication started with a qualification stage applying to two fuel elements and resulting in four fuel elements that were delivered to the RECH-1 reactor in November 1998. During this stage, the fuel fabrication process was submitted to a QA inspection by the reactor operator, and by the regulatory body. Besides, these four fuel elements were fabricated considering that they were going to be submitted to visual inspection during their irradiation. In this regard, only in these elements, the filter plate was removed from the filter box end piece [4].

- Standard fuel fabrication.
  During 1999 and up to the first quarter of 2000, 19 standard fuel elements were produced and 7 fuel elements are expected for the end of 2000. The main results of this fabrication are the following:
  - In the fuel plates process, a total of 594 fuel plates had been fabricated. Only 14 fuel plates had presented non-conformances to specified values. The non-conformances were mainly in the fuel plate core length. The corrective action included extra cold rolling passes. Up to date, no dog boning has been detected in the inspections and only 3 fuel plates had presented non-conformances due to out of core fuel particles.
  - In the fuel element assembly process a total of 23 LEU fuel elements had been assembled. Pull tests gave an average value of 61 N/mm of fuel plate rolled swaged joint and in the fuel box the gap average value obtained was 3.18 mm with an assured value > 2.92 mm. For the final TIG welding assembly operations, a welding device that minimizes the distortion was implemented, thus delivering fuel elements fully compliant with dimensional tolerances.

Considering that the reference core configuration of the RECH-1 reactor requires 32 fuel elements, the LEU fabrication program indicates that the MEU to LEU fuel conversion will be possible by the end of the first semester of 2001, when the above condition will be fully satisfied. The 50 LEU fuel elements goal is expected by the end of the first semester 2002.

4. In- core follow-up

The main objective of the in-core follow up is to know and register the behavior of the leader fuel elements under irradiation up to 55% burn-up in the RECH-1 reactor [5]. This activity was started with the introduction in December 1998 of the leader fuel elements LR-01L and LR-02L

into the reactor core at peripheral positions. These fuel elements were instrumented with thermocouples in order to measure inlet and outlet water temperature. In July 1999 the fuel elements LR-03L and LR-04L were introduced in the reactor. Their actual positions by September 2000, at a higher power density position in the reactor core, are presented in Fig. 2.

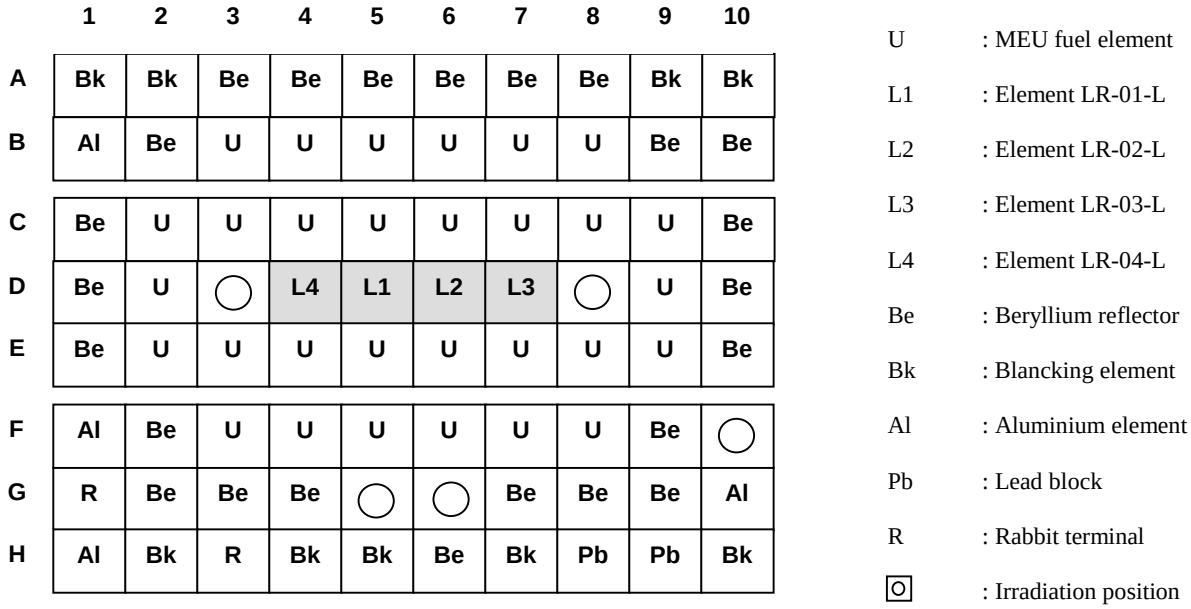

Fig. 2 Actual RECH-1 core configuration

Considering that for most of the time, the RECH-1 reactor has been operated at the nominal power of 5 MW in a continuos shift of 24 hours per week, 48 weeks per year, the 55 % discharge burn-up will be reached by the year 2005 in these fuel elements. The early irradiation of the leader fuel elements on one hand will anticipate in at least two years the irradiation behavior of the standard fuel elements, and on the other hand it has started a follow-up program that intends to cover the following points:

- Inspection: underwater visual inspection of the LEU fuel elements that will include video and photographic registers, sipping test of the fuel elements LR-03L and LR-04L, and implementation of a gamma scanning device for profile and average burn up determination.
- Monitoring: reactor power, operation time, inlet and outlet water temperature measurements in fuel elements LR-01L and LR-02L, and reactor water radiochemistry and chemistry analysis (pH, conductivity, Fe, Cu and Cl content).
- Neutronics calculations: Neutron flux, burn-up and maximum wall temperature for each leader fuel element.

The calculated burn-up of the leader fuel elements up to September 2000 is 10%, and no fabrication problems have been detected. Considering that CCHEN lacks of a hot cell for PIE, only visual inspections and verification of the coolant gap with a go/no-go gage will apply to these fuel elements when the 55% burn-up discharge level will be reached.

5. ISO 9001 implementation

CCHEN has addressed the quality issues involved in all its activities and particularly in this LEU fuel fabrication program via the implementation of a Quality System Management based on ISO 9001/2000. The decision for this implementation was taken at the end of the first semester of 1999. At that opportunity the scope of the implementation was ISO 9002/ 1995. In March 2000, a change towards the ISO 9001 scope was adopted, after a revision of the implementation progress, and after considering that this is the only scope that will apply by December 2000.
The finished activities indicate that a 70 % progress in this implementation has been achieved by September 2000, and a full implementation is expected by December 2000. The ISO 9001 certification for the LEU fuel fabrication process is expected by June 2001.

6. Fabrication and qualification optimization planning

The actual LEU fuel fabrication progress has pointed out the main issues where optimization is possible and/or necessary. They are summarized here.

- Fabrication issues
  - Reduction of the time spent on quality controls and replacement of manual inspection techniques with automated inspection techniques. This requires implementation and training in ultrasonic measurement techniques to control the metallurgical bond in fuel plates and automated fuel plates core metrology.
  - Development and implementation of the gamma scanning technique to measure the U^{235} content in all fuel plates.
  - Design optimization of the end pieces of the actual RECH-1 fuel element that will simplify the welding and assembling operations.
  - Development of the capability for fabricating fuel plates with a high U_3Si_2 density.

- Qualification issues.
  As presented in point 4, the actual operation of the RECH-1 reactor indicates that the 55% burn-up will be achieved at best in 2005. The only possible way to accelerate the irradiation results is the external irradiation in a high flux reactor. In this regard explorative actions had been taken in order to evaluate the technical and economical feasibility of this external qualification in which besides qualification issues, legal, transport and back-end issues are also involved.

7. Conclusions

The main conclusions at this stage of CCHEN's LEU fuel fabrication program are:
- CCHEN's Fuel Fabrication Unit has fabricated 23 LEU U_3Si_2 – Al fuel elements for the RECH- 1 reactor. The present fabrication schedule anticipates 32 finished LEU elements by June 2001, thus making possible the MEU to LEU conversion of the RECH-1.
- The four leader fuel elements are under irradiation in the RECH-1 reactor, and they have reached a 10% burn-up with no detected fabrication problems. The present operation schedule anticipates a 55 % burn- up by the year 2005, for these four fuel elements.

8. References

[1] IAEA -TECDOC-643, Research reactor core conversion guidebook, Volume 4, 1992.
[2] CCHEN Specification, "Especificaciones para elementos combustibles en base a siliciuro de uranio de bajo enriquecimiento para el reactor RECH-1 de la CCHEN", May 1997
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