STATUS OF THE RERTR PROGRAM IN ARGENTINA

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The Argentine Atomic Energy Commission started in 1978 the Reduced Enrichment Research and Test Reactors in the field of reactor engineering; engineering, development and manufac turing of fuel elements and research reactors operators.

This program was initiated with the conviction that it would contribute to the international efforts to reduce risks of nuclear weapons proliferation owing to an uncontrolled use of highly enriched uranium. It was intended to convert RA-3 reactor to make possible its operation with low enriched fuel (LEU), instead of high enriched fuel (HEU) and to develop manufacturing techniques for said LEU.

Afterwards, this program was adapted to assist other countries in reactors conversion, development of the corresponding fuel elements and supply of fuel elements to other countries.

INTRODUCTION

Totally embodied with the international efforts to reduce at its utmost the risks of proliferation, and in the conviction that the use of highly enriched uranium (HEU) in the research and tests reactors fuel elements could lead to its use for nuclear weapons, Argentina, through CNEA, firstly took part in the INFCE (IAEA) and later on, immediately after its beginning, in the RERTR (Reduced Enrichment Research and Test Reactors) International Program, which -with the same spirit- the Energy Department of USA started in 1978.

Many were the contributions that CNEA made to the RERTR Program as well as important were the contributions that CNEA received from it. It must be stressed those corresponding to the joint study between the Argonne National Laboratory (USA) and the Atomic Energy Commission (ANL-CNEA) (1) (10) that are being carried on since 1979; especially the facilities offered for the irradiation and postirradiation of fuel miniplates.

These knowledges developed by CNEA were presently transferred to South American and other developing countries, through training courses or bilateral agreements in the field of reactors and fuel elements.

Argentina is still interested in taking part in the RERTR International Program, not only to continue with optimization studies on fuel elements development, its manufacturing techniques and safe and economical operation of their research reactors, but also to have the possibility of applying the knowledge acquired to obtain 99 Mo from plates with high density low content of U (20% U-235).

BASIC SCOPE AND MAIN TASKS

The basic scope of the Program, still in force, is:

- The development and qualification under irradiation of fuels with high density of uranium to use LEU (20% U-235) instead of HEU (90-93% U-235) in research reactors in order to avoid -at maximum- changes in the fuel design and/or the characteristics of the reactor.

- Performance of studies on reactors physics, thermohydraulics and safety, in order to meet the best conditions necessary for the licensing of research reactors operated with LEU fuel elements.

To achieve these objectives, since the beginning CNEA performed several works on the fuel elements and reactors field. In nuclear fuel we began with lines of aluminides (UAl_x-Al) and oxides (U_3O_8-Al), pressuming that 20% U-235 could be supplied as oxide (U_3O_8) or metallic (U_{metal}) by its usual supplier, which up to that moment, was USA (1). Besides, it was also understood that, while 20% U-235 fuel elements were not available, the supply of uranium would be kept as 90% enriched U-235, in order to maintain the RA-3 operative. The truth was that, since 1979, 90% U-235 was not supplied and, as for 20% U-235 only reduced quantities were received in the form of U_3O_8 and U_{metal}, that only allowed the manufacturing of miniplates and 3 standard fuel elements. Therefore, for the manufacturing of the RA-6 and RA-3 complete core, Argentina had to get its 20% U-235 at the international market. This special circumstance made that CNEA, in order to ensure the operation of its RA-3 reactor included three new development fields in its initial program:

- Recovery of 90% enriched U-235, from plates manufacturing wastes and liquid wastes, accummulated through several years.
- Conversion of UF_6 to U_3O_8.
- Technology of uranium enrichment.

All thermohydraulic, neutronic and safety studies related to the RA-3 were performed, having reached the conclusion that, if fuels with uranium densities of 3 gU/cc could be obtained, the RA-3 reactor would be able to operate without making significant changes.

The experience obtained through the studies performed in the areas of reactors as well as fuel elements, made that CNEA passed on this knowledge to South American and other developing countries through courses and bilateral works.

STATUS OF THE ACTIVITIES PERFORMED

The works performed, the present state and future prospect of the Program in Argentina are herewith briefly described.

- Technology of fuel elements manufacturing

According to the original program, as well as to what it was added as a consequence of not having received the uranium necessary to operate the RA-3 reactor, the following activities were performed:

Recovery of 90% enriched uranium from manufacturing wastes

Treated materials:

Fussion salts	Approx. concentration	0,1 to 5 Ug/100g
Fussion slag	"	1 to 8 "
Crucibles	"	0,5 to 1 "
Fuel elements alloys plates	"	4 to 5 "
Different solid wastes	"	0,1 to 0,5"
Different solutions	"	20 to 100 ppm

Recovering and transformation scheme can be observed in Fig. 1. This material recovered as U_3O_8, was afterwards converted to metallic uranium through a calciumthermal process, for which the corresponding laboratories were mounted. The manufacturing of fuel elements for the RA-3 reactor continued with the alloy obtained by metallic uranium casted with aluminium. This whole process allowed the recovery of enough quantity of 90% uranium (about 8 kg UT) to manufacture the fuel elements that made possible the operation of the RA-3 reactor from 1982 till the present.

- Conversion of UF_6 into U_3O_8

When Argentina tried to buy 20% enriched U-235 in the international market, only UF_6 was available. Therefore, methods for its conversion into U_3O_8 had to be developed, taking into account the special characteristics of the U_3O_8 powder required for the manufacturing of high density fuel plates (more than 3 gU/cc). This originated works performed at laboratory scale, development of processes, manufacturing techniques and development of licensing programs for installations and personnel, as well as the design, mounting and start-up of an U_3O_8 production plant. These works provoked a significant delay in the initial program, as well as higher costs than the estimated. The works performed shall be presented at this Meeting (5-9) and the installations shall be visited at the Constituyentes Atomic Centre (CAC) on Wednesday.

Fortunately, the results obtained have been satisfactory, which enabled us to take on the manufacturing of plates for the RP-0 and RA-3 reactors fuel elements.

In order to optimize the use of 20% enriched uranium and with the idea of decreasing the production costs, an alternative way of U_3O_8 production by spray-drying is being developed (25). Moreover, a project of a plant for the recovery of solid wastes and liquid effluents, generated during the different processes of conversion of UF_6 into U_3O_8, has been prepared.

- Low enriched fuel elements. Development and manufacturing

Three development lines were performed at CNEA:

U_3O_8-Al

UAl_x-Al

U_xSi_y-Al

Although as early as in 1980 it was necessary to decide on the line to use for manufacturing the RA-3 and RP-0 fuel elements, which was U_3O_8-Al, the development of the three lines was covered, having obtained at present the following results (Fig. 2):

U_3O_8-Al line: In 1978 it was started the manufacturing of miniplates. A first set of 4 miniplates, with densities between 2,46 and 3,12 gU/cc, was sent in 1981 to the Oak Ridge Reactor (ORR) for their irradiation. They showed an excellent behaviour after 87% Bu (14). In 1982/83 a second set of another 4 miniplates, with densities between 3,12 and 3,58 gU/cc was irradiated in the ORR, up to 91% Bu, also with excellent results (15).

Between 1985 and 1986, 2 standard fuel elements were manufactured, one of them is at present being irradiated in the RA-3 reactor and the other one to be irradiated in the ORR. At present, we are at the final stage of the RP-0 core manufacturing and the RA-3 reactor first core is being manufactured.

UAl_x-Al line: Miniplates that were successfully irradiated together with the U_3O_8 first and second sets in the ORR were also manufactured (15).

The high densities reached and their excellent behaviour, up to 91% Bu, must be stressed. This line is of special interest for 45% U-235 Medium Enriched Uranium (MEU).

In the second set a 3,09 gU/cc density was reached, because UAl_2 was used.

Works with UAl_2+U were also performed. As the free uranium, during the rolling process, reacts with the free Al of the matrix, forming UAl_x, the density can reach 3,5 gU/cc or more. The advantage of introducing free uranium in the U_xSi_y line can be seen in the postirradiation of the ORR standard fuel elements (19).

It must be pointed out that after 91% Bu the postirradiation tests showed a negative thickness change, contrary to what happens with U_3O_8 or U_xSi_y.

U_xSi_y-Al line: In the beginning CNEA only worked with U_3O_8-Al and UAl_x-Al lines. After the irradiation of the first set of miniplates in the ORR, and due to the excellent results obtained by the postirradiation analysis, experts from ANL recommended CNEA to aim at the U_xSi_y (U_3Si or U_3Si_2) lines. Therefore, in the second and third irradiation sets in the ORR, 3 and 7 miniplates were introduced respectively. They reached 91% and 83% Bu with satisfactory results (15). The postirradiation test of the third set is pending.

Owing to the confidence of these results, CNEA manufactured in 1986 a standard fuel element with a 4,8 gU/cc density, to be irradiated in the ORR with the completed first core of that reactor together with fuel elements manufactured by CERCA, NUKEM and B&W.

In parallel with the development of these three lines, a new manufacturing plant of fuel elements had to be designed, built and set-up. It had to cover the three processes developed taking into account, especially, powder lines, operators safety as well as UAl_x and U_3Si_2 powders of highly pyrophoric characteristics. This plant was already described in Petten in 1985 (13) and you will be able to visit it on Wednesday at the Constituyentes Atomic Centre.

This plant, that is now in operation, can produce one fuel element per day. All standard fuel elements abovementioned have been manufactured in it. Moreover, a QA system that guarantees the quality of the fuel produced has also been performed (18).

All the development capacity performed in design, mounting and set-up of this plant has also been useful for an Argentine public enterprise which could commercialize this plant abroad. Also Chile, which through the Argeninte-Chilean agreement, could mount its own fuel manufacturing plant based on the knowledge and experience transferred by CNEA.

- Irradiation tests and postirradiation examinations

As abovementioned, CNEA has performed its miniplates irradiation tests and postirradiation examinations using the facilities offered by the RERTR Program, through the ANL-CNEA joint study. Unfortunately, the closing of the ORR at the beginning of this year brought a real shock to CNEA because, not only became impossible to irradiate two standard fuel elements (one U_3O_8-Al and the other U_3Si_3Al) that CNEA manufactured in 1986, but also because future tests are in jeopardize. At present, the RERTR Program's authorities have advised us on the possibility of irradiating in the Swedish R-2 reactors the 2 fuel elements that could not be irradiated in the ORR. This possibility is considered as very improbable. However, CNEA expects that, with the help of the RERTR Program's authorities and particularly through the up to now very efficient ANL-CNEA joint program, these problems that delay considerably the Argentine development in this field can be solved.

Owing to these circumstances, CNEA has also considered the possibility of performing irradiation tests in its RA-6 and RA-3 reactors in spite of the low neutronic flux of these reactors.

- Manufacturing of miniplates to obtain radioisotopes

Using the capacity of producing high density uranium plates, 90% U in U-235 miniplates are manufactured at the Fuel Elements Manufacturing Plant, which allow the production of 99 Mo after their irradiation in the RA-3 reactor. At present, it is foreseen to produce 99 Mo irradiating plates with 20% U in U-235, using the development obtained in high density siliciures miniplates. This development is also foreseen within the RERTR Program and, especially, within the ANL-CNEA joint study.

- Engineering reactors area

. Reactors Physics

It was apparent from the beginning of the reduced enrichment program in CNEA that it was needed an ample variety of experimental data to validate and check the 2-D or 3-D diffusion codes that were used in CNEA for the design of the 20% enriched cores of MTR research reactors (RA-3 and RP-10).

Therefore, a series of subcritical, near critical and hipercritical experiments were planned to have enough data to test the calculated codes. These experiments were done in the RA-2 critical facility.

The first experiments were undertaken for a series of water reflected 90% enriched cores from far subcritical to critical. Pulsed neutron technique was used to obtain, prompt neutron decay constants, and reactivity values (20).

Afterwards, a series of more complex experiments for subcritical cores were planned with different reflectors arrangement (graphite and beryllium). Prompt neutron decay constant, reactivity values and rod worth for control rods, were obtained, using Gozani Garellis-Rusell and Simmons King interpretation for pulsed neutron experiments (21).

A second series of experiments were undertaken for near critical cores. A description of some of these experiments is found in two papers presented in this meeting (MTR Core Experiments Analysis Part I-II). In these experiments reactivity and bucklings values were obtained (20).

A third level of experiments were done for hypercritical cores (4% K/K), in which asymmetrical reflector (position) and control rod insertion, give a more reliable approximation to an operating research reactor and suitable benchmark to test 3-D diffusion code.

Finally, reactor parameters of our operating research reactor (RA-3) were also taken into account.

These experiments contributed to improve the CNEA capability for the design of the MTR 20% enriched research reactor (RP-10) and the core conversion of the RA-3 research reactor.

. Activities developed in neutronics

The following activities were performed:

- Participation in IAEA's benchmark in 1979.
- Reproduction of some calculations done by ANL.
- Conceptual parametric study for the conversion of the RA-3 reactor.
- Calculation of the RA-3 reactor actual reactivity.
- Densities and geometries study for the conversion of the RA-3 reactor, including beryllium reflectors.
- Joint work with ANL to verify densities, geometries, etc. values obtained.
- Criteria analysis to absorb experimental errors.
- Calculations reactivity coefficient and cinetic parameters for the RA-3 with HEU and LEU.
- Final design of the LEU fuel element (δ =3 gU/cc; meat thickness 0.7 mm and 290 gU-235/FE).
- RA-3 final safety report preparation.
- Definition of equilibrium core configuration and fuel management.
- Detailed calculation model and reliable system for the RA-3 operation follow-up.

The development of a rods calculation method and a neutronic and thermohydraulic factibility study of a fuel element UO_2 rod type enriched from 5 to 8% in U-235 for the RA-3 reactor were also performed.

This group worked intensively in the RP-10 Project. The works performed were presented at international meetings (10) (16) and at national meetings (22)(23)(24).

Main activities in thermohydraulics

This group devoted to two fundamental tasks:

- Thermohydraulic design for the re-design of the core and accident analysis of the RP-10 reactor.
- Thermohydraulic design and accident analysis for the change of enrichment in the RA-3 reactor and its use at 7 MW.

Unfortunately, it was necessary to make the decision of the RP-10 fuel element design when the manufacturing technology of plate-type fuels, with 20% U-235, only allowed to reach a maximum density of 2.3 gU/cc, which determined the design of a 16 plates fuel, being therefore a less efficient thermohydraulic design. Instead, for the RA-3 reactor, in which the final design decision was made when the manufacturing technique of plates at 20% had already reached 3 gU/cc, a 19 plates fuel could be designed. Hence, the thermohydraulic design was more efficient.

- Support to other countries

. Training courses

CNEA organized, for Latin American countries, training courses related to research reactors core conversion to be operated with LEU, as well as the development and manufacturing of the corresponding fuels. Details of these courses shall be given in this Meeting (4).

. Works performed through bilateral agreements

Within the Argentine Program related to research reactors conversion, joint works in reactors and/or fuels were made with different countries, such as Peru, Chile, Uruguay and Iran. These works were performed either through bilateral national agreements or IAEA.

CONCLUSIONS

The necesity of reactors conversion from HEU to LEU fuels brought about a significant economics and human resources inversion to Argentina, especially regarding fuel development and manufacturing. However, today it is clearly demonstrated that this effort has been profitable because, not only contributed positively to the reduction of proliferation risks that implies HEU use, but also meant for CNEA's experts a technological challenge that they were able to succeed. For this reason, as we have worked intensely at CNEA during these years, we are convinced that the technological level reached in research reactors and fuel engineering as well as the facilities for development and manufacturing plants for the plate-fuel production at present available allows us to undertake the fuels supply to other countries and to develop facilities suitable for this purpose.