PROGRAM DESCRIPTION FOR THE QUALIFICATION OF CNEA-ARGENTINA AS A SUPPLIER OF LEU SILICIDE FUEL AND POST-IRRADIATION EXAMINATIONS PLAN FOR THE FIRST PROTOTYPE IRRADIATED IN ARGENTINA

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Abstract

In this report we present a description of the ongoing and future stages of the program for the qualification of CNEA (Comisi6n Nacional de Energia At6mica, Argentina) as a supplier of low enriched uranium (LEE9 silicide fuel elements (FE) for research reactor Particularly we will focus on the characteristics of the future irradiation experiment on a new detachable prototype, the post-irradiation examinations (PIE) plan for the already irradiated prototype P04 and an overview of the recently implemented PIE facilities and equipment.
The program is divided in several steps, some of which have been already completed It includes: development of the uranium silicide fissile material, irradiation and PIE of LEU silicide miniplates and irradiation and PIE of several full-scale prototypes. Important investments have been already carried out in the facilities for the FE production and PIE.

1. PROGRAM FOR THE QUALIFICATION OF CNEA-ARGENTINA AS A SUPPLIER OF LOW ENRICHED URANIUM SILICIDE FUEL FOR RESEARCH REACTORS.

1.1.PROGRAM DESCRIPTION

The main goal of the Argentinean Silicide Fuel Program is to qualify the technology and the associated facilities developed by CNEA, for the production of fuel elements for research reactors, using uranium silicide as fissile material. The program consists of the following stages:

- Development of processes, at laboratory scale, to prepare the uranium silicide fissile material. This phase is completed.
- Several miniplates Of U3Si,,, dispersed in an aluminum matrix were fabricated at CNEA and irradiated in the Oak Ridge Research Reactor (ORR), in the framework of the Reduced Enrichment for Research and Test Reactors Program (RERTR). The PIE of these miniplates were carried out in the Oak Ridge National Laboratory [1], [2].

  One FE with uranium silicide (U3Si2) was manufactured at CNEA with the aim of performing a complete irradiation experiment in the ORR. Experts of the Oak Ridge National Laboratory qualified the production processes. This fuel element (P04) was later irradiated in the RA-3 reactor in Argentina. Some non-destructive poolside inspections have been carried out on this fuel element and CNEA is presently initiating non destructive and destructive PIE in hot cells.

- Upgrading and equipping the existing fuel fabrication facilities to manufacture full-scale silicide fuel elements for the Argentinean RA-3 reactor.
- Design, fabrication, irradiation in the RA-3 and PIE of two full scale FE (P06 and P07). The envisaged bum-up will be in the order of 50% of the initial ... U mass. Instrumentation will be provided during irradiation and a complete set of non-destructive and destructive PIE will be performed in the pool and in hot cells.
- Implementation of facilities and associated equipment to perform destructive and non-destructive PIE, in both pool and hot cells.

1.2. FABRICATION FACILITIES UPGRADING

A relevant process of improvement and upgrading of fabrication facilities has been carried out with the aim of setting up the equipment necessary for silicide material fabrication. The main achievements can be summarized as follows:

- Modification of the fuel fabrication glove boxes ventilation system, in order to ensure a protective, low oxygen atmosphere, for silicide fuel manipulation.
- Installation of a new induction furnace, computer controlled, for silicide material preparation.
- Emplacement in the glove boxes line of new equipment for particle size adjusting: jaw crusher and planetary ball mill.
- New equipment for quality control inspection of silicide fuel plates and fuel assemblies: X-ray inspection device and improvement of the metrology room.

1.3. FULL-SCALE IRRADIATION EXPERIMENT (P-06 PROTOTYPE)

The main purpose of this full-scale irradiation test is to verify the fulfillment of all the qualification criteria with respect to: corrosion resistance of the FE, mechanical rigidity, integrity (related to the release of fuel material or fission products), deformation by swelling or blistering (specially in relation with cooling channel dimensions) and clad surface temperature compatible with mechanical stability of the fuel.

1. 3. 1. Fuel Element:

This prototype is being designed as a detachable FE, to ease its underwater disassembling in the pool. Welding will be avoided as far as possible, pieces requiring attachment will be screwed or connected through easy removable mechanisms. The geometrical characteristics will be similar to the standard RA-3 FE. Two different versions, carrying 19 or 17 active plates, are being considered. The outer (active or not) plates will be fixed to both side plates, the rest of the fuel plates will slide on slots located on the side plates. Some neutronic and temperature instrumentation will be provided, including self-powered detectors, activation wires and foils and thermocouples. The fissile material for the meat will be U3Si2 prepared by high temperature melting of metallic uranium and high purity silicon. The final compact fissile core will be prepared by the usual procedures; aluminum powder will be used for dispersion.

A complete pre-irradiation characterization, in pile monitoring and PEE will be applied, with the aim of verifying all the requirements of the qualification program. Before irradiation the FE will be tested in a hydraulic test loop to measure cooling water flow versus pressure drop over FE height.

1.3.2. RA-3 Reactor:

The irradiation experiment will be performed in the Argentinean RA-3 reactor. This is a pool type reactor, refrigerated and moderated with light water. Cooling is provided by down-going forced convection. The core consists in 20 to 27 FE and 5 control elements. The equilibrium configuration at the moment of the irradiation will be, most probably, the one with 25 fuel elements, which corresponds to an average nominal power of 5 MW, so all the preliminary calculations for designing and licensing the experiment are being carried out these conditions.

1.3.3. Irradiation program

The irradiation positions in the RA-3 will be defined in accordance with the results of an exhaustive set of neutronic and thermal hydraulic calculations that are being carried out at present. Before irradiation or during the experiment the following controls will be performed:

- Reactivity measurements of the fresh fuel with the reactor at low power.
- On line monitoring of neutron flux and temperature.
- Visual inspections in the reactor pool, during reactor shutdown periods.
- Determination of spatial neutron flux distributions by neutron activation techniques

2. POST-HULADIATION EXAMNATIONS PLAN FOR THE FIRST LEU SILICIDE FUEL ELEMENT IRRADIATED IN ARGENTINA (P-04 PROTOTYPE)

A Uranium Silicide (U3Si2-Al matrix) prototype fuel element was fabricated in 1987 in Argentina as a part of the RERTR program,. At that time it was planned that this prototype would be irradiated at the ORNL Reactor and consequently its design and characteristics were the appropriate for that reactor. Shortly after that, the ORNL Reactor was shut down. Nevertheless, Argentina decided to go on with the program, and the prototype was modified to fulfil the requirements for irradiation in the Argentinean RA-3 Reactor.

The most important modification involved the straightening of all its plates, which had a curved shape; so the prototype was redesigned and reconstructed using the same active plates with another structural frame appropriate for the RA-3 grid. It was called P-04. Table I shows the main features of the P-04 prototype.

Enrichment	19.75%
Meat fuel matrix	U_3Si_2-Al
Number of plates	19
Plate thickness	1.3 mm
Meat dimension	585 x 60 x 0.55 mm
Coolant gap between plates	2.9 mm
U235 mass per plate	17.9 g
U235 mass into the element	340,33 g
Meat fuel density	14.8 g/cm^3

Table 1. Main parameters of the P-04 Prototype

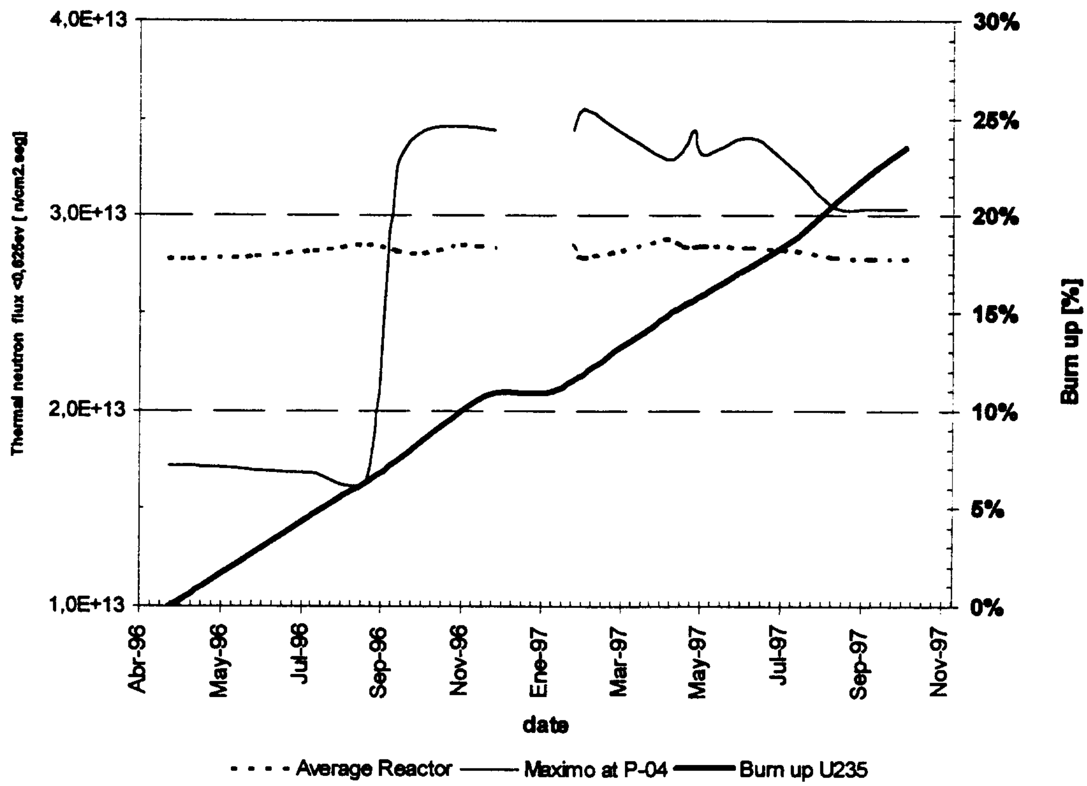

Figure 1. Irradiation history of the P-04 prototype. The gap indicates the largest shutdown; the short ones are not shown".

The irradiation was carried out in the RA-3 Reactor since April 23, 1996 until October 27, 1997. The P-04 prototype was irradiated at three different core positions. At first it was introduced in a peripheral position, then it was shifted to a position next to the core center, where it faced the maximum thermal flux (about 3.55E13 n.seg-l.cm-2), and finally it was shifted to another peripheral position. Figure I shows the irradiation history of the P-04 prototype in the RA-3 Reactor [3].

2. 1. FOLLOW-UP OF THE IRRADIATION BEHAVIOR

In order to follow-up the behavior of the P-04 during the irradiation, periodical visual inspections were planned. An ad-hoc station was installed at the rim of the pool. This station consists of two parts: the bottom part is a 4.5 m deep underwater shelf where the fuel element can be positioned either vertically or horizontally, and the upper part is an inverted telescope that allows to scan visually the whole external surface of the fuel element. The observation is done directly through a 40x-magnification lens mounted on the tube, where a photographic camera can also be attached. A pipeline with a suction pump was installed to remove the water heated by the fuel element, so as to avoid the upward convection flow that could blur the image.

By positioning the fuel element vertically and using an appropriate lamp situated just below the fuel **element nozzle, the gap between plates can be** easily estimated and later measured on the photographs. The inspections were performed immediately after the reactor shutdowns between normal operation cycles, it is not necessary to let the FE decay for cooling.

Figure 2 shows an operator performing the visual inspection with the described system.

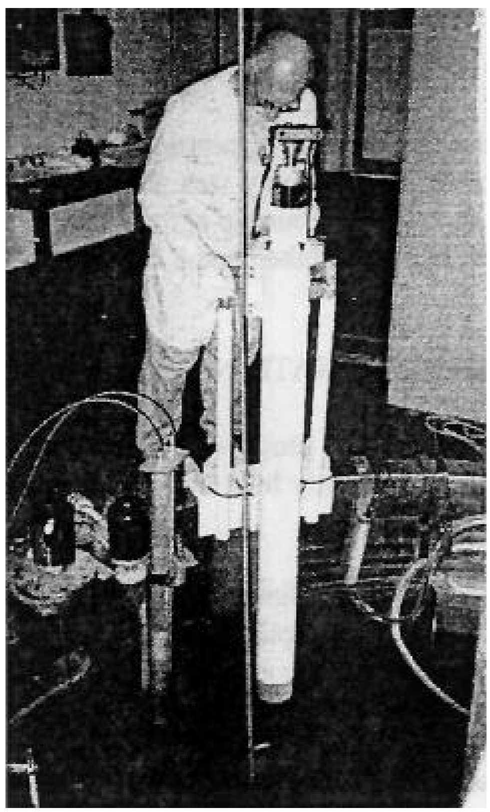

Figure 2. On-line visual inspection station at RA-3 pool reactor.

No anomalies were observed during the visual inspections. The P-04 showed a good general external appearance and no deformation of the assembly was noticed.

Examination of the coolant channels with the element backlighted showed the plates perfectly straight and flat. Neither bowing nor swelling were observed.

The external surfaces of both outer plates were found clean and did not show any sign of corrosion. Only when the burnup reached the value corresponding to the third dwelling in the core, a slight extended black stain appeared in the middle of the meat zone.

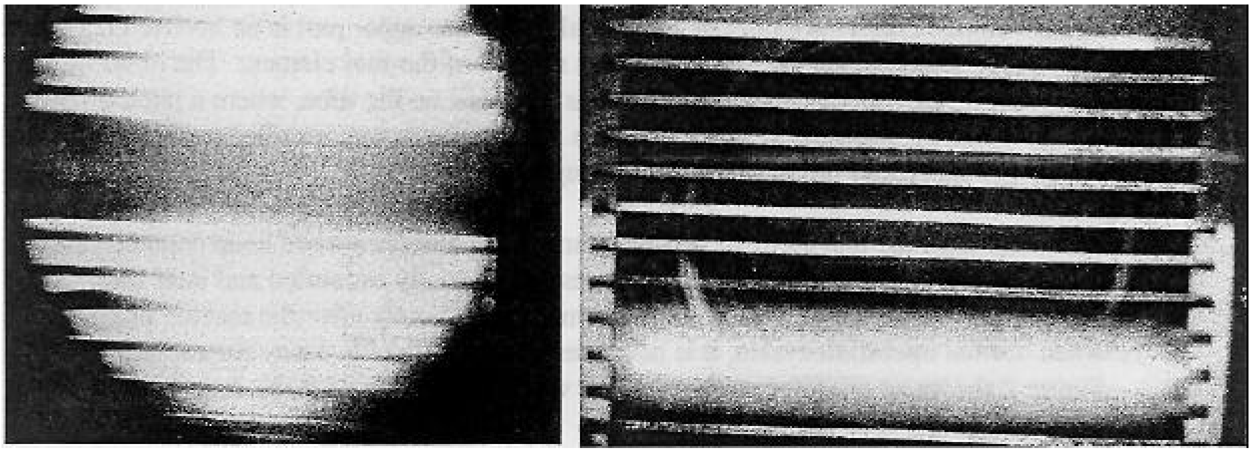

Figure 3 & 4. Backlighted and frontlighted photographs of the P-04 taken during visual inspection.

Despite the fact that the fuel element appearance seemed to be good, during its irradiation period a slight increase of the total activity was noticed in the pool, especially ^{133}Xe activity. As the P-04 had reached an important burnup at that time (ca. 23% of the initial ... U mass) the decision of ending its irradiation was taken and a PEE program was planned.

2.2. POST MADIATION EXAMINATION

The post irradiation examination program will be performed in our hot cells laboratory (LAPEP). These hot cells were recently built and the equipment for PIE is being implemented at present.

Nowadays LAPEP consists of two lines of hot cells, one for gamma active materials and another one with a gas-tight box for alpha-gamma active fuel materials. They have a 20 cm thick shielding made of lead bricks. The alpha-gamma line has four working posts and a small annex cell with a complete metallographic microscope. These cells allow the handling of radioactive sources of up to 200 Ci equivalent to 6OCo [4].

After a convenient decay time, the P-04 will be transported using a standard fuel flask to the LAPEP.

By the end of this year, according to the measurements performed in the Pool and to the calculations, the prototype will have a total activity of 2350 Ci (eq. ^{60}Co) and the dose rate at contact with a 20 cm Pb-shield will be 0,07 mSv/h [5].

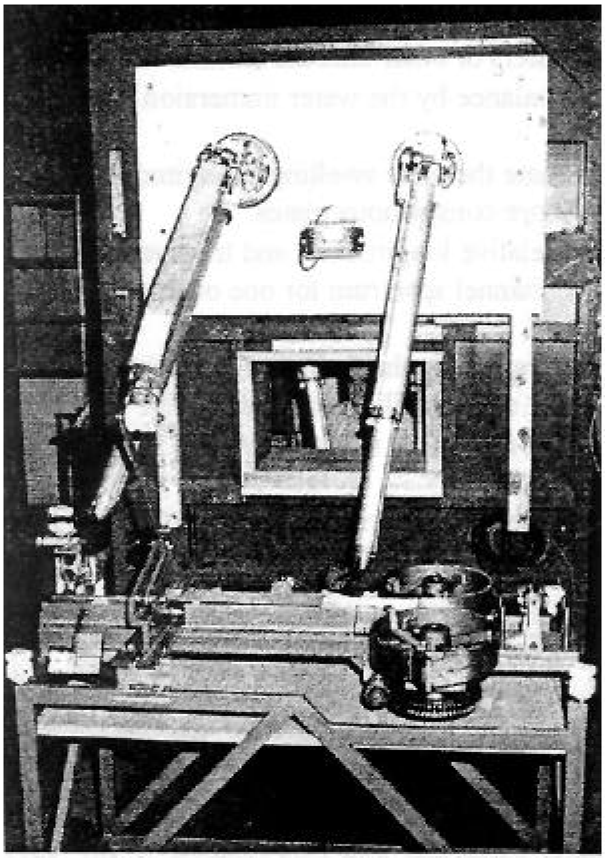

Figure 5. Machine for dismantling the fuel element being operated at the mockup.

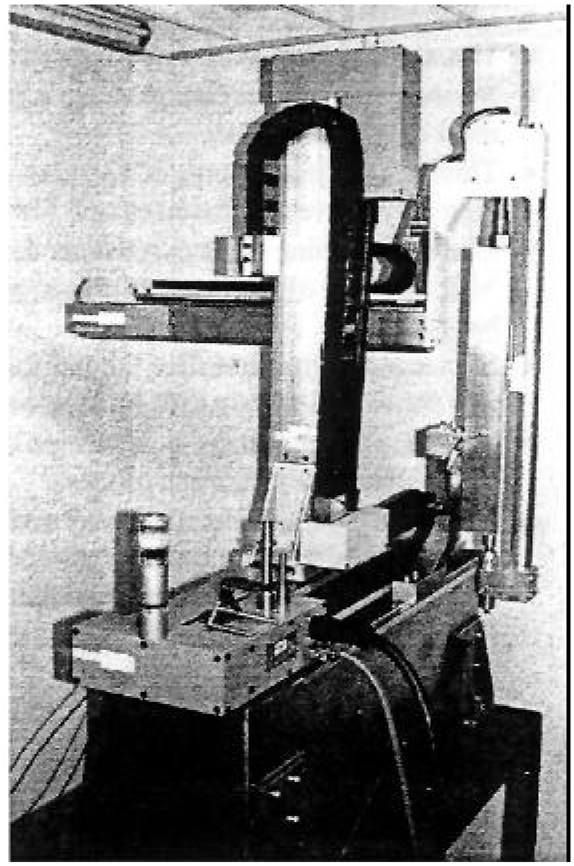

Figure 6. Standard Cartesian Robot used to perform scan testing in fuel plates.

The first task will be to dismantle the element so as to handle the fuel plates separately. A special machine was built for this purpose, which can disengage both structural side plates. By rolling these side plates the fuel plates are released, so they can be appropriately stored and tested individually. Operators are presently being trained with this machine in a working post telemanipulator mockup shown in Figure.

Because of the small size of the hot cells, versatile and multipurpose equipment was considered apt to perform at the same post the dimensional measurements, gamma scanning and other non-destructive testing using eddy current or ultrasonic gauges. This equipment consists of a standard Cartesian Coordinate Robot, which was modified and enhanced. A specific computer program drives the robot's three-axis movement to perform any directional scan. Figure 6 shows the robot carrying out a thickness profile of the fuel plate, using two opposite LVDT gauges.

PIE on P04 will be performed at LAPEP employing the above mentioned equipment and facilities. The PIE plan will include the following steps:

- Visual inspection of the fuel element.
- Measurement of the coolant channels gaps profile using a special blade probe with strain gauges.
- Dismantling of the element to prepare plates for individual examination.
- Visual inspection of all fuel plates to detect blisters or other unusual feature.
- Measure the volume change using a precision balance by the water immersion method, for most of the fuel plates.
- Thickness measurements of fuel plates to estimate the plate swelling. Longitudinal scanning along several axial lines of a few of the more conspicuous plates.
- Gamma scanning measurements to determine relative longitudinal and transverse burnup. Measurement of both analogue scan and multichannel spectrum for one outer and a few inner plates.
- Blister testing to determine the threshold temperature for the formation of blisters for only two plates. An ad-hoc split furnace was built for easy handling in the hot cells.
- Non-destructive testing to determine the more conspicuous spots and search for possible flaws, using eddy currents probes.
- Destructive cut for metallography and absolute chemical burnup analysis. A special punch was designed to draw a small fuel sample out of the plates. The cutting position will be selected according to previous examinations.
- Canning of the tested fuel plates for dry storage. The structural parts remaining will be disposed as medium level waste.

3. FINAL CONSIDERATION

The implementation and achievement of this PIE plan will be performed in the framework of the Implementing Arrangement for Technical Exchange and Cooperation in the Area of Peaceful Uses of Nuclear Energy between the Department of Energy of the United States of America and the National Atomic Energy Commission of the Argentine Republic, through a joint project with Argonne National Laboratory. An expert from the RERTR program group will be present at the hot cells laboratory to assist Argentinean professionals, at some predefined crucial stages during the PEE process.

4. REFERENCES

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