24^{th} INTERNATIONAL MEETING ON
REDUCED ENRICHMENT FOR RESEARCH AND TEST REACTORS
November 3-8, 2002, Bariloche, Rio Negro, Argentina

RERTR ACTIVITIES IN ARGENTINA

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ABSTRACT

The Atomic Energy Commission of Argentina has been an active participant of the RERTR program since 1978. An important milestone of the Argentinean RERTR program was the development and manufacturing at industrial scale of U_3O_8 dispersed fuel and its subsequent application to the conversion of the RA-3 reactor core to LEU fuel.

More recently, our activities were focused on the development of U_3Si_2 fuel with a density of 4.8 gU/cm^3 and the improvement of the manufacturing process of this type of fuel. The program to qualify CNEA as a supplier U_3Si_2 dispersed fuels is scheduled to finalize by mid 2003. To hasten this program the main research reactor of Argentina, the RA3, raised its power from 5 MW to 8 Mw in October this year. This is an intermediate step in the program to increase RA-3 power to 10 MW

Currently, one of the main objectives is to develop and qualify the technology for the production of high-density LEU fuel elements using U-Mo alloy. An original way to produce U-Mo powder (the HMD process) was developed and its being upgraded to plant scale production.

Another significant progress was the development of LEU targets for the production of ^{99}Mo, in the form of miniplates prepared with dispersed LEU U-Al_x.

The shipment to USA of 207 MTR spent fuels containing US origin highly enriched uranium, successfully carried out in the end of 2000, is another remarkable achievement of the Argentinean RERTR program. This activity was carried out in the framework of the United States Foreign Research Reactor Spent Nuclear Fuel Acceptance Program. The fuels were fabricated in Argentina and used in the RA-3 reactor from 1968 to 1987. The inventory of the shipped HEU spent fuel consisted in 166 standard assemblies and 41 control assemblies.

1 Introduction

The National Atomic Energy Commission of Argentina (CNEA) initiated its participation in the Reduced Enrichment for Research and Test Reactors Program (RERTR) twenty-five years ago. Since then, many important achievements have been attained. At present, a wide range of activities are in progress, some of them as a cooperative undertaking with the USA Department of Energy and the Argonne National Laboratory.

This paper is organized as a progress report for the period 2001-2002, a brief reminder of some of the most important accomplishments of the program and an overview of the current RERTR activities are presented, emphasizing the ongoing R&D and qualification programs on high density fuel, especially on the new U-Mo fuel.

2 History

One of the most relevant achievements of CNEA´s RERTR program was the development and manufacturing at industrial scale of U_3O_8 dispersed fuel, which allowed the subsequent conversion of the RA-3 research reactor core to LEU fuel.

The experience gained through this program allowed CNEA to initiate its activities as a qualified domestic and international supplier of LEU MTR fuel. All, domestic and international, supplies have been carried out maintaining a strict bond to the RERTR philosophy and contributed effectively to disseminate RERTR criteria worldwide. Some examples of the above-mentioned activities are listed below:

- 1986 - 1987, LEU fuel elements and control fuel elements for the PERUVIAN CRITICAL FACILITY RP-0.

- 1987 - 1988, LEU fuel elements and control fuel elements for the ALGERIAN 1 MW RAE REACTOR.

- 1989 - 1992, LEU fuel elements and control fuel elements for the conversion from HEU to LEU of the IRANIAN 10 MW TRR REACTOR.

- 1990 - 1993, LEU fuel elements and control fuel elements for the conversion from HEU to LEU of the ARGENTINE 5 MW RA-3 REACTOR and its subsequent refueling.

- From 1994 on, the technology to produce standard RA-3 type MTR fuel was transferred to a private company. Who has been continuously refueling the reactor since then.

- 1996 – 1997, LEU fuel elements for the EGYPTIAN 20 MW MPR REACTOR.

As a whole more than 600 fuel elements have been shipped. So far, no defective or failed items have been reported by the customers.

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3 U_3Si_2 Program

The purpose of the program is to qualify CNEA as a supplier of Al dispersed U_3Si_2 MTR fuel, with densities up to 4.8 gU/cm^3. The program includes the following stages:

- Development and optimization of the process to obtain the uranium silicide fissile material
- Fabrication and irradiation of miniplates
- Manufacturing of full size fuel plates
- Full scale fuel irradiation

The completion of the first three stages of this program was reported in previous RERTR Meetings [1, 2] and RRFM Topical Meetings [3, 4, 5]. The full-scale irradiation stage is being carried out in the Argentine RA3 reactor. At present there is no evidence of any undesirable behavior or fuel failures related with the new type of fuel material.

The irradiation of the first full scale U_3Si_2 fuel (P-06, an RA3-like assembly) started in 2000; during 2001 the design and fabrication of the second fuel element (P-07) of the U_3Si_2 program were completed. This fuel element includes thinner fuel plates, with thinner cladding and thicker meat and also a larger number of fuel plates. As reported in [1], before the fabrication it was necessary to set up and fine-tune the manufacturing processes of the thinner fuel plates.

Contents of U and Si in the U3Si2 powder range within 91,55-91,82 % and 7,47-7,61 % respectively. The next table shows the typical content of relevant impurities for the different batches of U3Si2 used for P-07 fabrication [6].

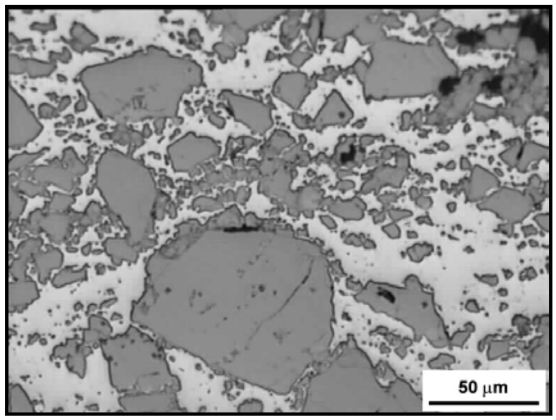
Impurity	**B**	**Cd**	**Co**	**Cr**	**Hf**
Average Content [ppm]	0,3	1	1,8	8	14

The density of the resulting powder ranges from 12,02 to 12,08 g/cm3. The average content of particles under 50 μm is 38 %(w).

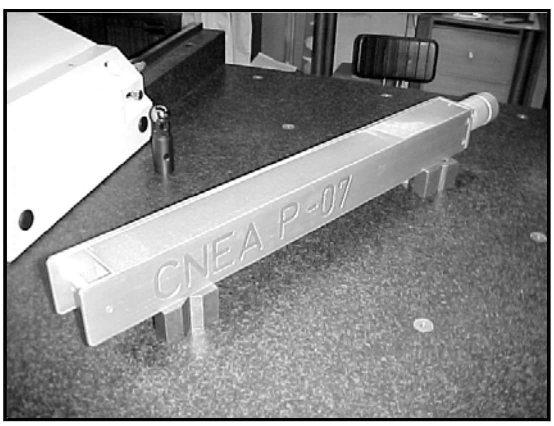
The following Table shows typical numbers for plate thickness distribution

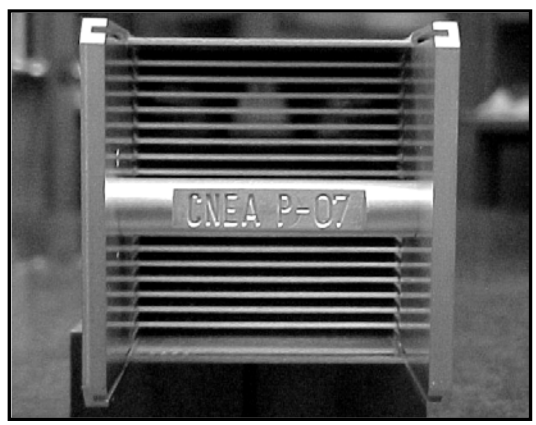
		Specification (Nominal)	Average	Max	Min
Fuel plate	**External**	1,475	1,47	1,49	1,44
	Internal	1,325	1,32	1,35	1,3

The picture shows the result of the metallographic examination of the meat and a typical distribution of silicide particles after rolling.



The next two pictures show the final shape of the fuel element P-07.





The irradiation of both U_3Si_2 MTR fuel elements (P-06 and P-07) is presently carried out in the RA3 reactor. At present, both fuel elements are in highly rated positions and the average burnup at the moment of writing is approximately 30 % for P-06 and 15 % for P-07. Due to the recent rise of the RA3 power to 8 MW, the irradiation time will be significantly reduced. Under these new conditions, it is envisaged that the irradiation of these two fuel elements will be completed by mid of 2003. The target burnup in both cases is 55 %.

4 U-Mo Program

CNEA is an official participant of the international program to qualify U-Mo as a nuclear fuel for research reactors; this program is organized and managed by the DOE-ANL RERTR program. In parallel with the activities in the international program CNEA is carrying out a domestic qualification program of the technology and facilities involved in the manufacturing of aluminum dispersed U-Mo nuclear fuel for research reactors. In the following paragraphs an overview of the above-mentioned undertakings is presented.

4.1 International Program

Participation of CNEA in the International Program will include the fabrication of two fuel assemblies using spherical U-Mo powder supplied by KAERI and non-spherical U-Mo powder prepared by the HMD process, recently developed at CNEA. Uranium density in both fuel assemblies will be 7 g/cm^3, the highest density value used in this phase of the qualification program.

The successful completion of the qualification program will qualify at the same time CNEA as a manufacturer of U-Mo dispersed fuels for research reactors with uranium densities up to 7 g/cm^3 and the U-Mo powder produced by the HMD process as a suitable material to be employed in the fabrication of U-Mo fuel for research reactors.

The most important characteristics of the fuel elements to be fabricated by CNEA are as follows:

- Fuel meat densities: 7.0 gU/cm^3
- Fuel meat alloy: U-7Mo
- Powder type: atomized, and HMD
- Fuel element features:
    - 20 plates, 1.52 mm thick
    - Meat thickness: 0.65-0.76 mm
    - Cadmium wires in side-plate grooves
    - Fabricated by CNEA
    - Two elements

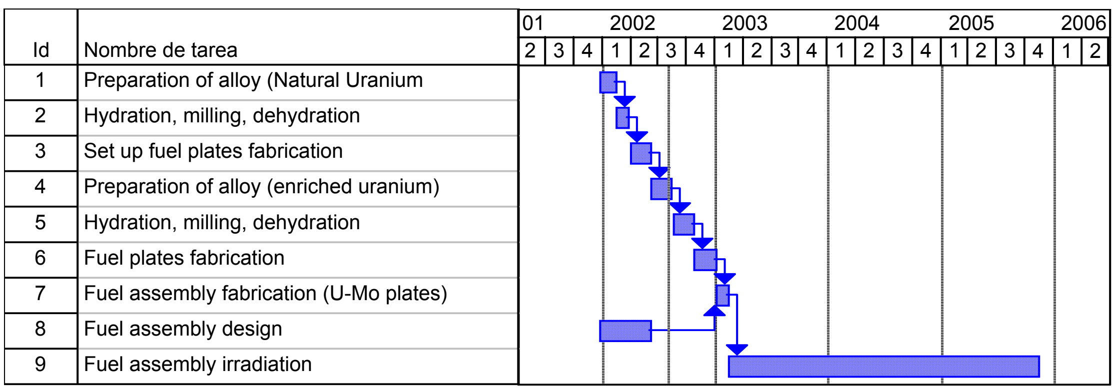
4.2 Domestic Qualification Program

The aim of the national U-Mo program is the qualification of the technology and facilities involved in the manufacturing of aluminum dispersed U-Mo nuclear fuel for research reactors. The program will be completely carried out in CNEA facilities.

The main activities of CNEA´s domestic program to qualify the technology for the production of high-density LEU fuel elements using U-Mo alloy can be summarized as the follows:

- Preparation of the U-Mo alloy
- U-Mo Powder characterization
- Set up of miniplates and fuel plates manufacturing

The schedule of the domestic program is shown in the following figure. Some delays may arise due to the overlapping of some of the activities of this program with doings of the international qualification program, which has a higher priority.



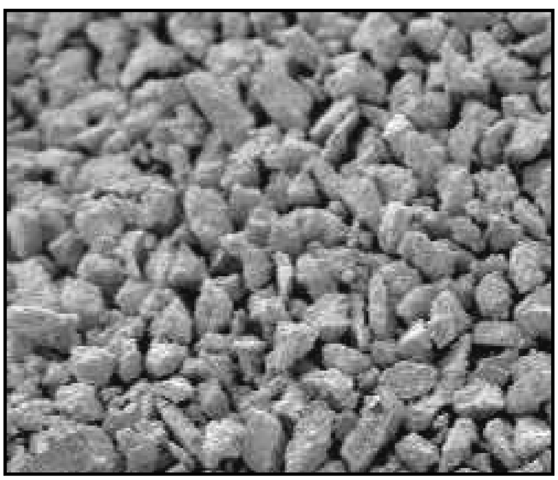
4.3 Development of the HMD process to produce U-Mo powder

Powder metallurgy technology offers different alternatives to prepare uranium-molybdenum (U-Mo) alloy particles in the size range (< 150 µ) needed as raw material for the fabrication of material testing reactors (MTR) nuclear fuel elements. Since as cast U-Mo is a ductile alloy, conventional milling alternatives used with brittle materials are not applicable.

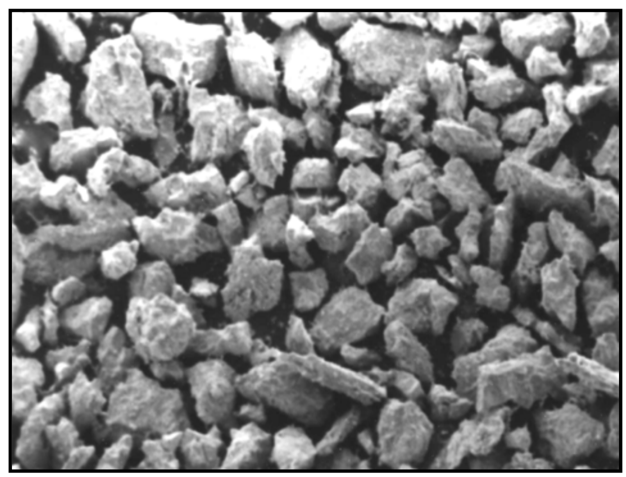
Centrifugal or gas atomization are the two more generalized high yield methods for metallic powder production. The major drawback of these alternatives is that since particles solidify in an inert gas atmosphere flight, big chambers are needed. High initial equipment capital investment is necessary, for a process usually requiring the preparation of small batches, limited to a few pounds, because of safety conditions imposed on the manipulation of an enriched uranium alloy. Hand and lathe filing, and wheel grinding, have been also considered as possible processes.

These alternatives are usually associated with additional treatments of classification, purification from introduced debris or rounding of filings by milling and scrap reprocessing.

The above-mentioned considerations were the driving forces to initiate the development of a new fabrication process. This undertaking concluded successfully with the recent discovery by CNEA of the massive hydriding of uranium-molybdenum alloys in the γ phase structure that produces a brittle interstitial compound that can be readily milled. This is the starting point for the hydriding-milling-dehydriding -HMD- process of powder production. This CNEA proprietary process, that is an original solution for the drawbacks of alternative methodologies, will be used to prepare the U-Mo powder for the CNEA´s fuel elements to be irradiated in the HFR Petten, in the framework of the RERTR international qualification program.

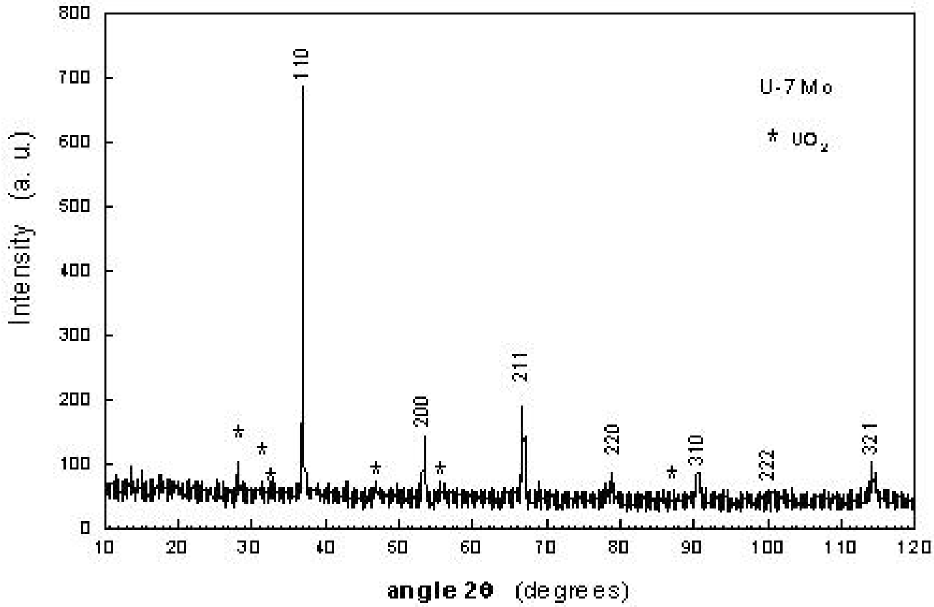


U-7Mo hydride powder



U-7Mo powder obtained by HMD process

Morphologically HMD powder is very similar to silicide powder, thus allowing an easy selection of the particle size distribution, appropriate for fuel plates fabrication and for the optimum in-reactor utilization [7].



X ray Diffraction of U-Mo alloy obtained by the HMD process

5 LEU Targets for Mo^{99} Production

A significant achievement for the period 2001-2002 is the implementation, at production plant scale, of the LEU targets for the preparation of ^{99}Mo. The new targets developed by CNEA are miniplates prepared with dispersed LEU $U\text{-}Al_x$ [8].

The application of these LEU targets in the ^{99}Mo facility was carried out without introducing any relevant modification to the equipment or processes employed with the HEU targets used so far. The radiochemical treatment of the irradiate LEU targets is performed maintaining the geometry and alkaline processing of the former HEU targets. The yield of the new LEU process is comparable with that of the previous HEU method [9].

6 Shipping RA-3 Spent Fuel to USA

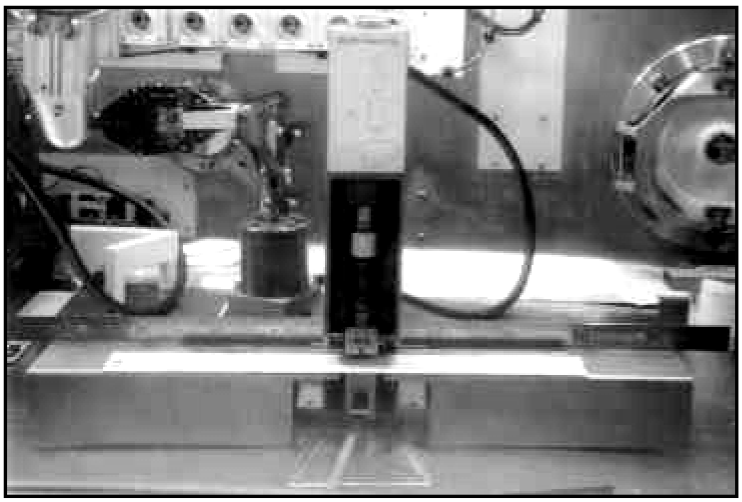
The shipment to USA of 207 MTR spent fuels containing US origin highly enriched uranium was successfully carried out in the end of 2000, in the framework of the United States Foreign Research Reactor Spent Nuclear Fuel Acceptance Program. The fuels were fabricated in Argentina and used in the RA-3 reactor from 1968 to 1987. The spent fuel inventory consisted of 166 standard assemblies and 41 control assemblies [10].

The fuel conditioning operations inside the storage facility (transference of the assemblies to the operation pool, fuel cropping, fuel re-identification, loading in transport baskets, etc.) were carried out by CNEA personnel and the loading of the filled baskets in the transport casks (NAC – LWT) using intermediate transfer systems, were performed by NAC personnel (DOE's subcontractor) with the support of CNEA staff.

7 Progresses on Destructive Post irradiation Examinations

The activities in the hot cells continued during this period with the destructive PIE of the P-04 silicide prototype fuel element. Chemical absolute burnup determination, metallographic and SEM examinations were carried out [11]. The main purpose of this work was to set up different standard PIE techniques in the hot cells, that will be applied in the future steps of the qualification program.

The picture shows the punching machine designed to obtain samples for absolute burnup determination, inside the hot cells.



8 Conclusions

Remarkable progresses in different RERTR activities have been achieved during the 2001-2002 period. The U_3Si_2 qualification program is proceeding as planned and, after the increase of the RA-3 reactor power to 8 MW in October 2002, it is scheduled to finish by mid 2003.

CNEA is actively participating in the international program to qualify high density U-Mo fuel and will fabricate two full-size U-Mo fuel assemblies with fuel meat densities of 7.0 gU/cm^3, to be irradiated in the Petten HFR. In parallel with the international qualification program CNEA launched a domestic program to qualify U-Mo fuel.

The hydriding-milling-dehydriding (HMD) process to produce U-Mo powder is fully developed at small scale and is being upgraded to plant capacity.

The use of HEU in ^{99}Mo production was definitely eliminated in Argentina, after the implementation of the new LEU targets developed by CNEA.

207 MTR spent fuels containing US origin highly enriched uranium were successfully shipped back to USA in the end of 2000, in the framework of the United States Foreign

Research Reactor Spent Nuclear Fuel Acceptance Program.

New destructive PIE techniques are available at CNEA´s PIE facility and will be employed in the U_3Si_2 and U-Mo qualification programs.

9 References

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