ADVANCES AND HIGHLIGHTS OF THE CNEA QUALIFICATION PROGRAM AS HIGH DENSITY FUEL MANUFACTURER FOR RESEARCH REACTORS

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ABSTRACT

One of the main objectives of CNEA regarding the fuel for research reactors is the development and qualification of the manufacturing of LEU high-density fuels.

The qualification programs for both types of fuels, Silicide fuel and U-xMo fuel, are similar. They include the following activities: development and set up of the fissile compound manufacturing technology, set up of fuel plate manufacturing, fabrication and irradiation of miniplates and plates, design and fabrication of fuel assembly prototypes for irradiation, post-irradiation examination and feedback for manufacturing improvements.

This paper describes the different activities performed within each program during the last year and the main advances and achievements of the programs within this period.

The main achievements may be summarized in the following activities:

- Continuation of the irradiation of the first silicide fuel element in the RA3
- Completion of the manufacturing of the second silicide fuel element, licensing and beginning of its irradiation in the RA3
- Development of the HMD Process to manufacture U-Mo powder (PUMA project)
- Set up of fuel plates manufacturing at industrial level using U-Mo powder
- Preliminary studies and the design for the irradiation of miniplates, plates and full scale fuel elements with U-Mo and 7 gU/cm3
- PIE destructive studies for the P-04 silicide fuel prototype (accurate burnup determination through chemical analysis, metallography and SEM of samples from the irradiated fuel plates)
- Improvement and development of new characterization techniques for high density fuel plates quality control including US testing and densitometric analysis of X-ray examinations.

The results obtained in this period are encouraging and also allow to foresee a wider participation of CNEA in the international effort to qualify U-Mo as a new material for the manufacturing of research reactor fuels.

1 Introduction

CNEA, the National Atomic Energy Commission of Argentina is focusing its activities regarding fuel for research reactors on the development and qualification of LEU high-density fuel manufacturing, mainly based on uranium silicide and U-xMo alloy.

As described in previous presentations [1-4], the qualifications programs for both types of fuels, Silicide fuel and U-xMo fuel, include similar activities. These activities are: development and set up of the fissile compound manufacturing technology, set up of fuel plate manufacturing, fabrication and irradiation of miniplates and plates, fabrication of fuel assembly prototypes for irradiation, post-irradiation examination and feedback for manufacturing improvements.

The purpose of the program is to demonstrate that CNEA's technology to manufacture high density fuels (namely U3Si2 and UMo) for research reactors is sufficiently proved and stabilized and, thus, that CNEA stands as a qualified supplier of this type of fuel elements

This paper describes the different activities performed within each program during the last year and outlines the main advances and achievements within this period.

2.1 Silicide fuel activities

The main activities regarding silicide fuels were the manufacturing of the second fuel element of the qualification program, its licensing and the irradiation of both fuel elements in the RA3 reactor.

2.2 Second silicide fuel element (P-07)

During this year the design and fabrication of the second fuel element belonging to the U3Si2 fuels qualification 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 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. These batches were obtained in quasi-industrial stable conditions [5].

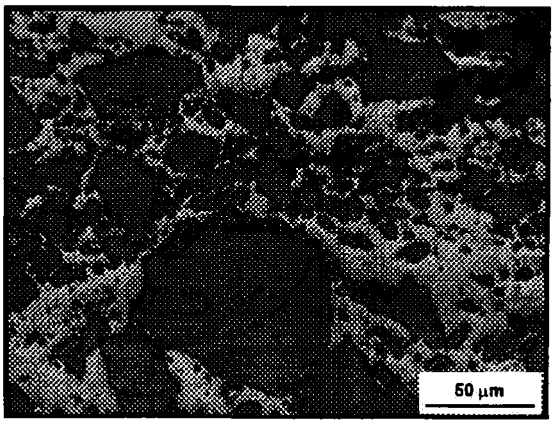
Impurity	B	Cd	Co	Cr	Hf
Average Content [ppm]	0,3	1	1,8	8	14

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).

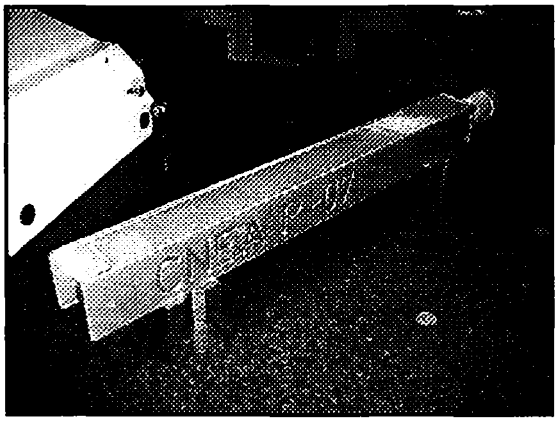
The following Table shows typical numbers for plate thickness distribution

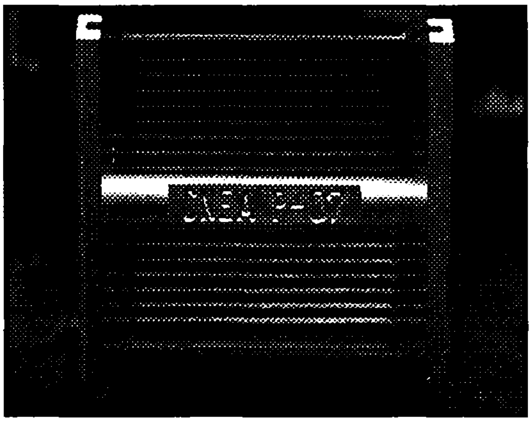
		Specification (Nominal)	Average	Max	Min
Fuel plate	External	1,475	1,47	1,49	1,44
	Internal	1,325	1,32	1,35	1,3

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.





2.3 Irradiation of the silicide fuel elements

The irradiation of the fuel elements P-06 and P-07 is carried out in the RA3 reactor. The irradiation of P-06 started in a peripheral position because of a requirement of our licensing authority, but now both fuel elements are in highly rated positions and the average burnup at the beginning of 2002 is 19 % for P-06 and 6 % for P-07. The irradiation of these fuel elements will be completed by the end of 2002 for P-06 and in March 2003 for P-07. The target burnup in both cases is 55 %.

3 U-Mo Fuel Activities

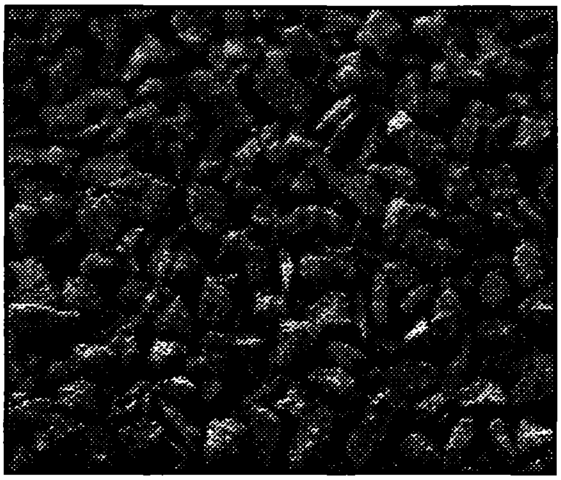
The main activities that constitute CNEA's program to develop and qualify the technology for the production of high-density LEU fuel elements using U-xMo alloy are the following:

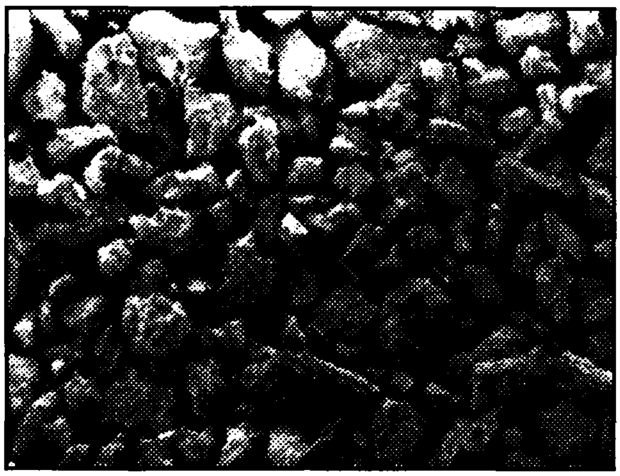
- **Procurement of the UMo alloy**
- **Hydriding, Milling and Dehydriding**
- **UMo Powder characterization**
- **Set up of miniplates and fuel plates manufacturing**
- **Fuel plates manufacturing**
- **Design, fabrication and licensing of one UMo fuel element**
- **Irradiation in the RA3 reactor**

3.1 Development of the HMD Process to manufacture U-Mo powder

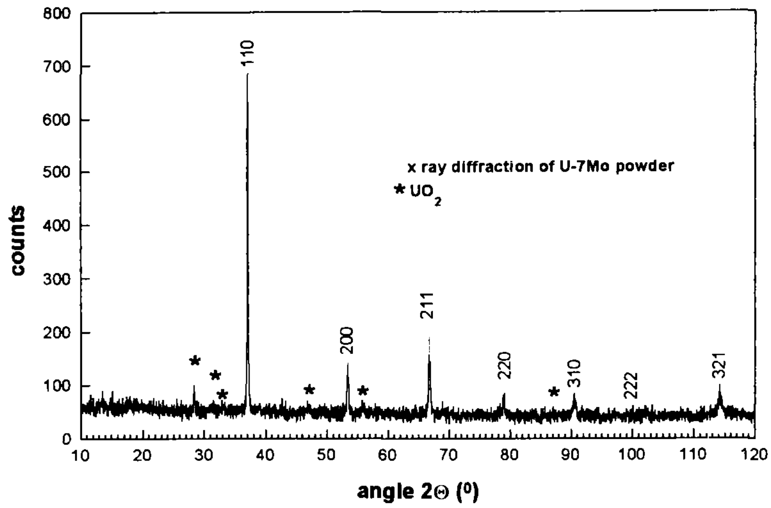
A massive hydriding of U-7%(w)Mo in γ (gamma) phase has been achieved [6]. The fragile compound allows the grinding of the hydride to the desired granulometry with less than 50% fines. After removal of the hydrogen, molybdenum homogenization is enhanced and no traces of the as cast structure remains. The development of this manufacturing process called HMD is being completed with the final tuning of the particles internal morphology and the particles size distribution. Process automation is being performed before going to an industrial full-scale production.

The following pictures show from left to right the shapes of both the hydride powder and the U-Mo powder





The next picture provides a typical X-ray diffraction diagram of the U-Mo particles obtained with the HMD process.



3.2 Set up of mini-plates and full scale fuel plates manufacturing using U-Mo powder

To continue with the set up of the fuel plates manufacturing process eight miniplates were fabricated recently. Four with U-7Mo powder supplied by KAERI and prepared by centrifugal atomization. The others with HMD powder. In both cases the loading was 7 gU/cm^3. The volume fraction of U-Mo in the meat is 44 %.

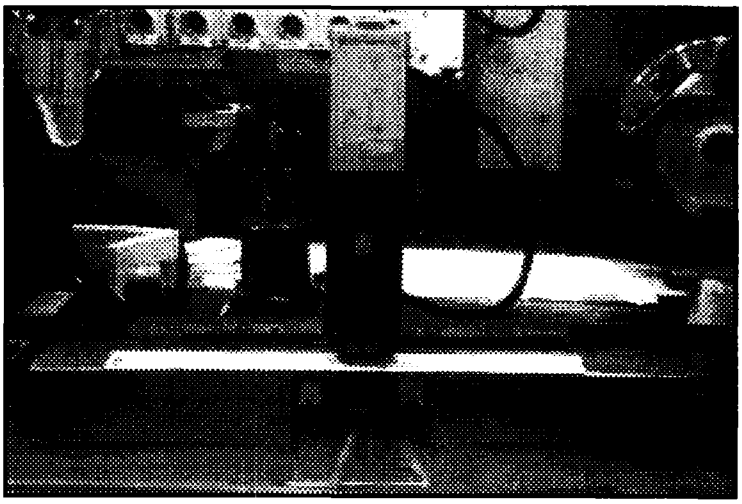
The result of the comparison between both materials is slightly favorable to the HMD powder, mainly because the shape of the particles is comparable with the silicide particles shape. However additional work will be necessary to improve the homogeneity of the U distribution and the amount of stray fuel particles outside the meat zone.

Two full-scale fuel plates with powder supplied by KAERI and a loading of 7 gU/cm^3 were also manufactured. In this case the result of the U distribution shows that this property is clearly dependent on the procedure to fill the die and on the expertise of the operator. This work was performed under a cooperation agreement with ANL.

4 PIE destructive studies for the P-04 silicide fuel prototype

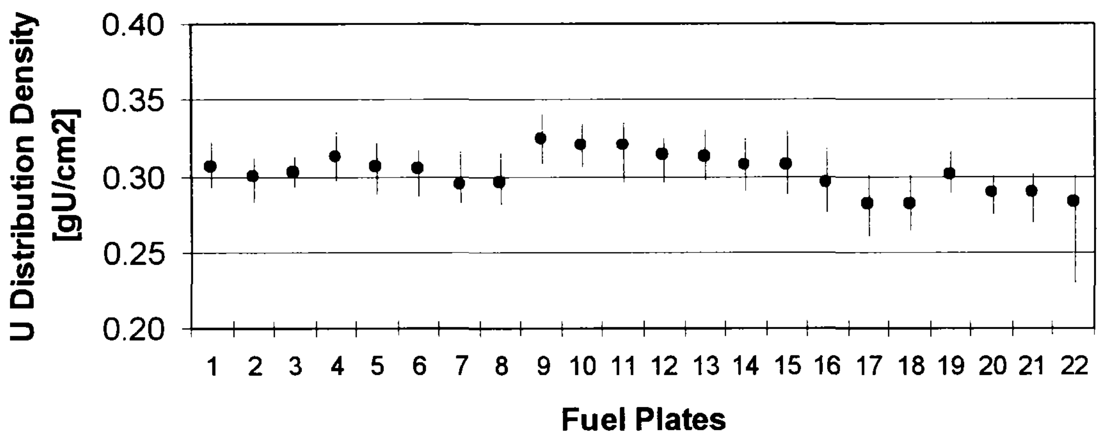
The works in the hot cells continued during this period with the development and procurement of samples from irradiated fuel plates of the P-04 silicide fuel element for the accurate burnup determination through chemical analysis and for the metallographic and SEM examinations.

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



5 Improvement and development of new characterization techniques for high density fuel plates quality control

To improve the quality control procedures of fabricated fuel plates, the densitometric analysis of X-ray examinations was set up and implemented during the last year. The calibration of the method was performed using samples where the U content was checked through chemical determination. P-07 fuel plates were tested using this technique. The following chart shows as an example the distribution of U density in the central zone of the fuel plates manufactured for P-07.



Works for the development of ultrasonic testing of fuel plates are also in progress.

6 Conclusions

CNEA has continued in the high-density fuels area with the qualification as U_3Si_2 fuel manufacturer, which is now in the irradiation phase. Significant advances were obtained in the development of the HMD process to fabricate U-Mo powder and in the set up of fuel plates manufacturing with this kind of fissile material. The results obtained in this period are encouraging and also allows to foresee a wider participation of CNEA in the international effort to qualify U-Mo as a new material for the manufacturing of research reactor fuels.

7 References

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