Irradiation of full size UMo plates
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ABSTRACT

An important development program for a UMo MTR fuel has been launched in France. The goal of the French working group is to develop a high performing and reprocessable fuel before the end of the US return policy. This paper is focussed on the fabrication of full-sized UMo plates with LEU (Low Enriched Enrichment) and their irradiation in OSIRIS reactor which was started on the 22nd of September. The results of the plates inspection are presented here as well as the irradiation conditions.

1. INTRODUCTION

An agreement has been signed this year by five parties (CEA, CERCA, TECHNICATOME, FRAMATOME and COGEMA) for the development of a high performancing LEU fuel using uranium-molybdenum alloys. The UMo alloys have been selected for their high density, their thermal stability [4], their behaviour under irradiation [5] & [6] and for their reprocessing capacities.

The aim of this important development program is to have a world wide qualified fuel before the end of the US return policy for spent fuel. The different steps of this program have been scheduled according to this dead line.

The feasibility of UMo fuel plates has been demonstrated [1] by CERCA in 1997 on full sized plates with depleted uranium and with densities up to 9 gU/cm^3. For two years, the process has been constantly improved in order to be able to produce enriched full-sized plates for irradiation tests.

This papers presents the status as of October 1999.

2. ENRICHED FUEL PLATE MANUFACTURING BY CERCA

2.1 Powder fabrication

The UMo alloys chosen contain 7% and 9% of molybdenum.

They have been made by casting uranium and molybdenum followed by a heat treatment.

It has been checked that the heat treatment leads to a homogenous γ phase of uranium molybdenum alloy, as shown by the result of an X-ray diffraction figure.

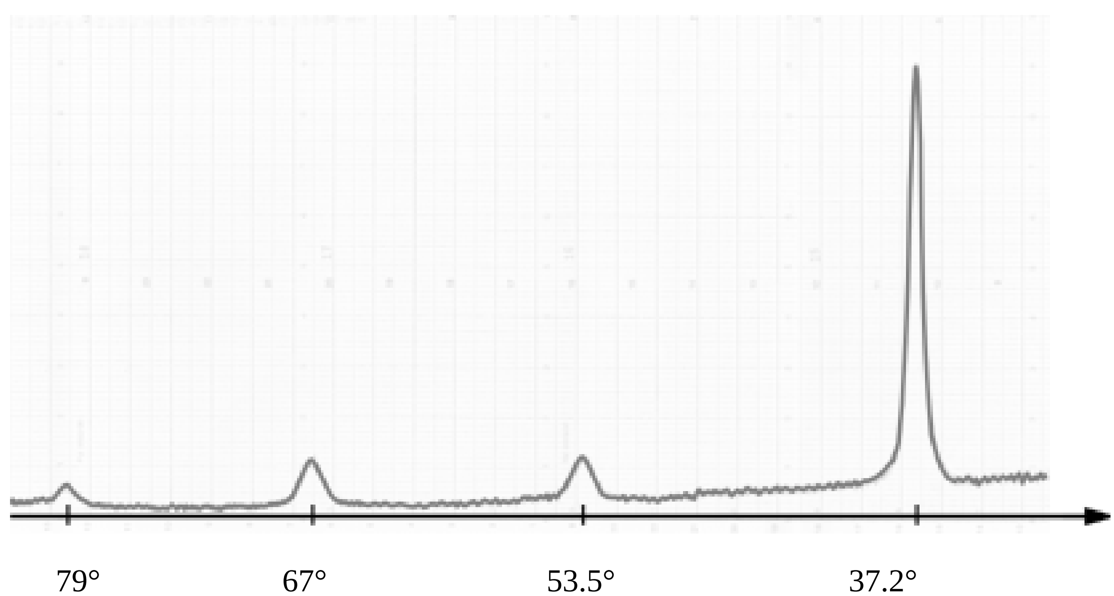


Fig.1 : X-ray diffraction on UMo alloy ingot

The powders have been made by temporary means of production: they have been ground.

The morphology of the UMo powders is shown in figure 2.

Fig 2 : ground UMo powder

On the other hand important studies have started on powder fabrication by atomisation.

2.2 Fuel plate manufacturing

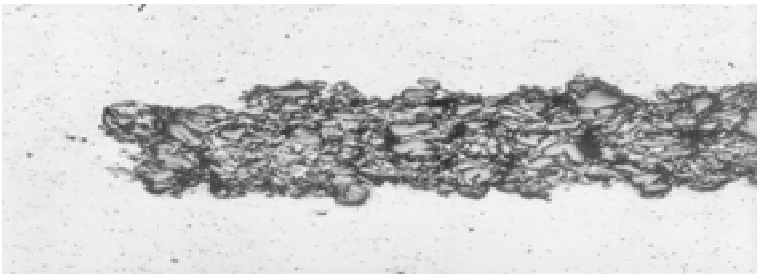
CERCA masters the manufacture of high loaded plates due to a proprietary advanced process which allows densities up to 6 gUt/cm^3 with U_3Si_2. This process has been successfully improved to solve the problem of mixing aluminium and UMo powders that have very different densities. This process is available both for ground and atomised powders.

The volume fraction of fuel particles of both plates is 50 %. With such a volume fraction the densities are 8.1 gU/cm^3 for UMo 7% and 7.8 gU/cm^3 for UMo 9%.

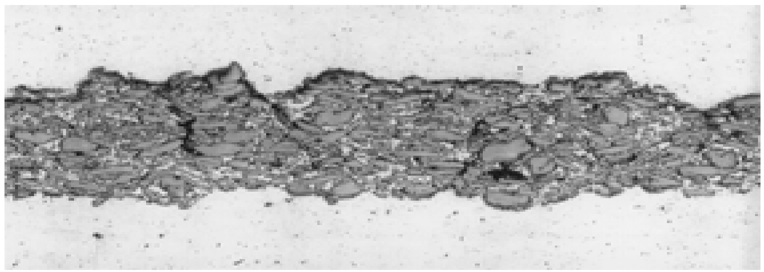
3. FUEL PLATE INSPECTION

3.1 Destructive examination : micrographs

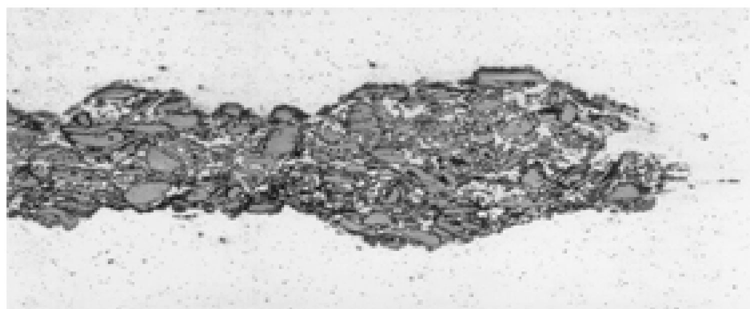
The aim of these examinations is the measurement of the meat and cladding thickness. It shows the arrangement of the particles in the meat : nearly all the space is occupied by UMo particles . The figure 3 shows the meat in the current part and in the dog bone area.



Dog bone area



current part



Dog bone area

Figure 3 : micrographs of the UMo plates (9% Mo)

3.2 X-Ray X-RAY films

Films are used to check the meat dimensions. The results are conform to the specifications.

3.3 Homogeneity of uranium distribution

The homogeneity of uranium distribution is quantitatively inspected by means of a radiographic system with an X-ray spot that scans the length of the plate. The uranium density is determined by measuring the absorption of the beam.

The figure 4 shows the variation of the uranium density along the meat on UMo 7% and UMo 9% plates. The homogeneity is better than $\pm$20%.

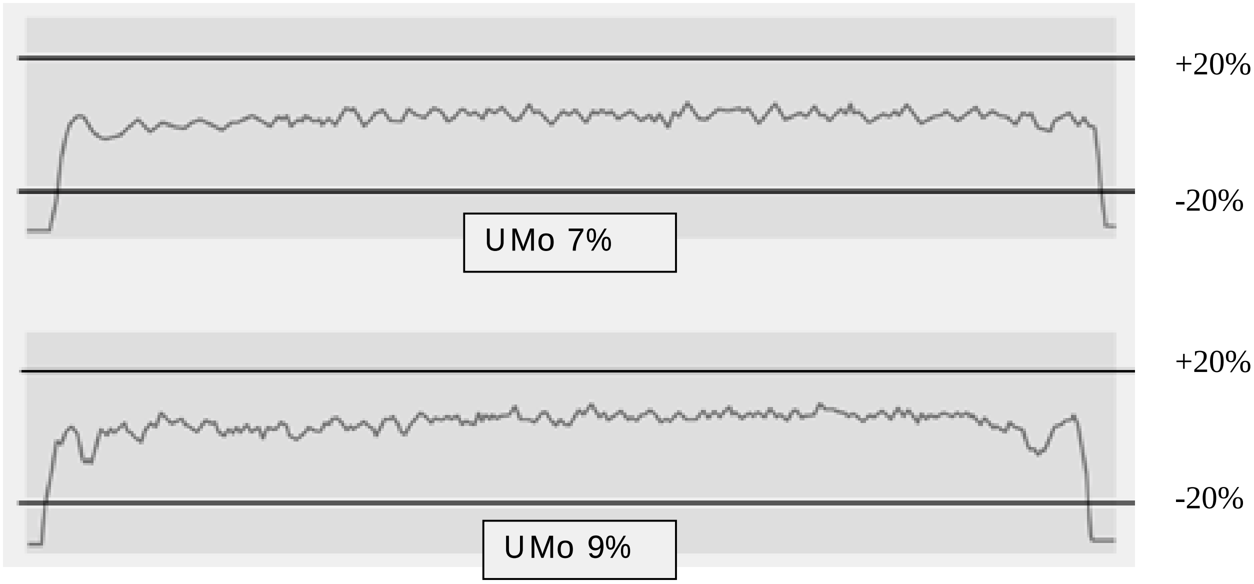
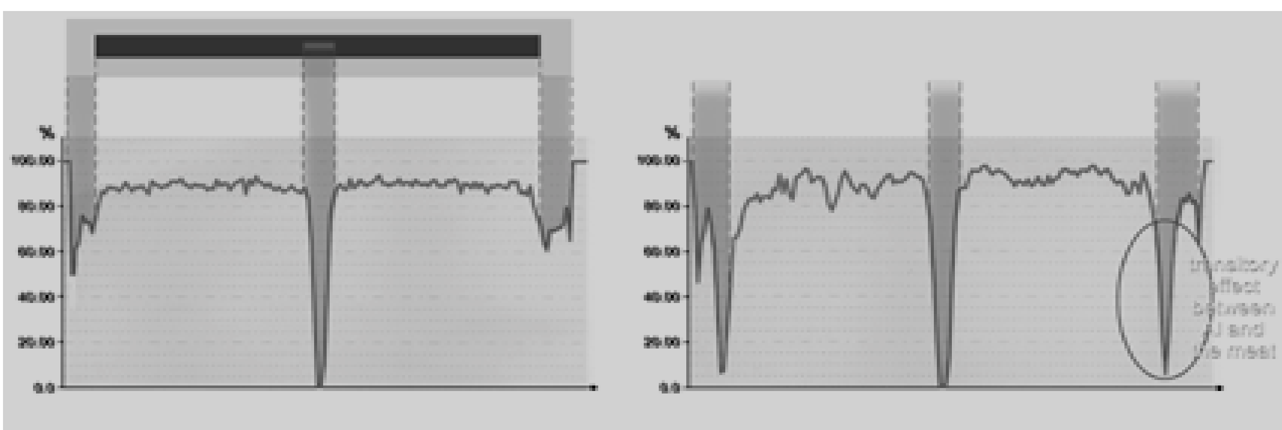


Figure 4: homogeneity of uranium distribution

3.4 Ultrasonic inspection

The aim of this inspection is to detect a delamination of the meat or a lack of bonding that did not lead to blistering.

Ultrasonic inspection has been carried out on fuel plates although it has previously been demonstrated [2] that this technique is limited by the difference in density between the meat and the aluminium of the edges. The transitory effects in the edge zone creates signals that are very similar to defect signals as shown in figure 5.



UAl_x plate ($1.2 gU/cm^3$) UMo plate ($9gU/cm^3$)

Figure 5 : Ultrasonic signals on a UAl_x plate ($1.2 gUt/cm^3$) with a standard defect and on a UMo plate without defect.

4. IRRADIATION IN OSIRIS REACTOR

4.1 Irradiation device

The aim of the IRIS irradiation device is to irradiate of experimental plates for research reactors. Subsequently, the objective of these irradiations is to qualify fuel plates that present new characteristics such as meat thickness, fissile medium, density, enrichment…), and to characterise their behaviour versus the burn-up (swelling measurement, absence of cladding rupture, …).

The irradiation device has the same external size as a standard U_3Si_2 fuel element for OSIRIS (section, top and bottom end fittings…). It can accept four plates (either inert or fuel plates) that are separated by four inert plates made of aluminium.

The irradiation device is made up of a body linked to a top set that prevents the plates from sliding out during the irradiation (down-top flux in the core). This top set is retracted during inter-cycles in order to remove the plates for the swelling measurement.

4.2 Swelling measurement device

The IRIS swelling measurement device has been designed for the measurement of irradiated experimental plates. The activity of these plates requires an immersion in 3 meters of water.

The plate to be measured is slid between two grooved uprights. Two probes in opposition measure the thickness, and the results are stored in a computer. The probes can move vertically or horizontally on the surface of the plate with step motors. Two standard gauge plates are fixed on the device to allow the calibration of the system before each measurement

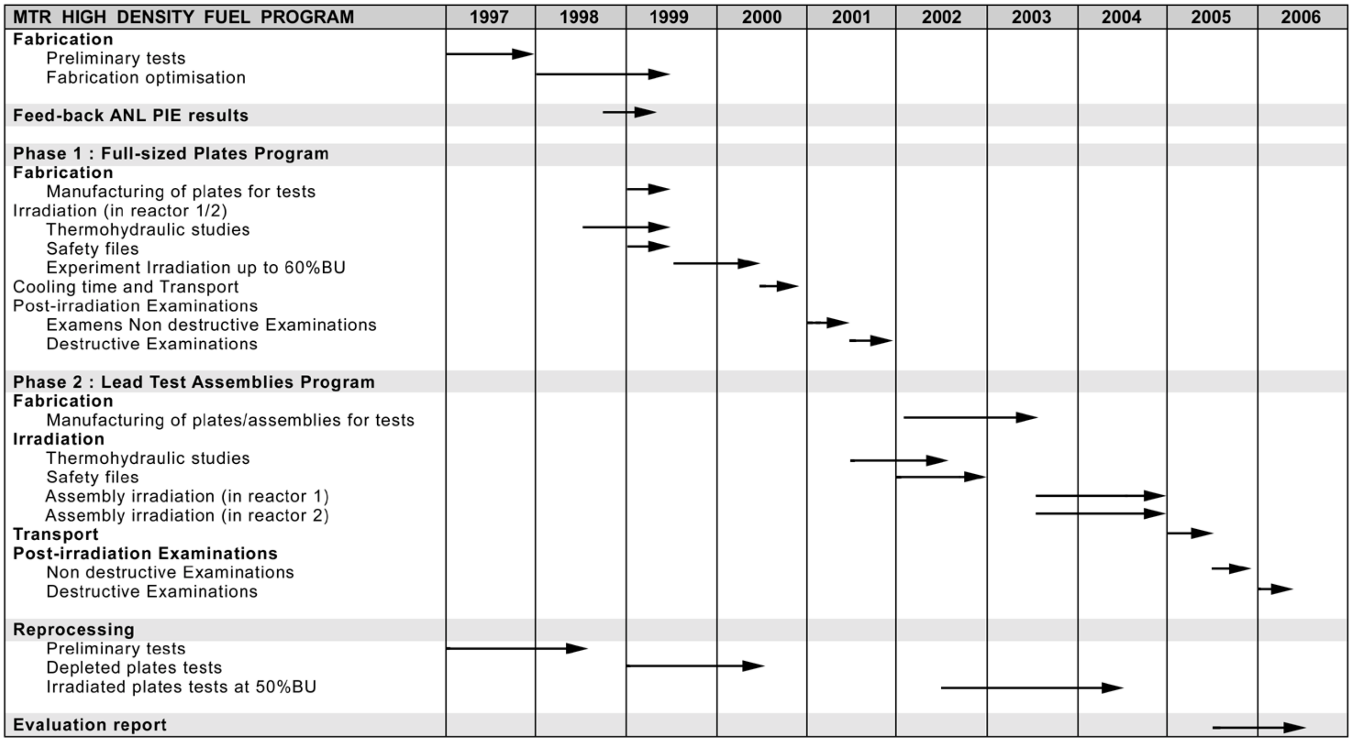
4.3 Irradiation conditions

The two plates are placed in the irradiation device called IRIS that is loaded in the reactor core.

The channels are heated from one side and the flow velocity is about 8 m/s. The thermal neutron flux in the plates is about 10^{14} n/cm^2/s. The power density in the UMo plates varies from about 3.5 kW/cm^3 at the beginning of the irradiation to about 2.5 kW/cm^3 at the end of the irradiation that is to say when a burn-up of 50% is reached. The maximum temperature of the cladding is about 110°C and the outlet cooling water temperature is about 60°C.

5. TIME SCHEDULE

The time schedule of this development program is presented hereafter.



6. CONCLUSION

The time schedule of the program has been respected.

The fuel plates were delivered at end of July. They were loaded in the OSIRIS reactor on the 22nd of September and the reactor diverged during the following night.

Swelling measurements are planned between irradiation cycles and after the last cycle. The irradiation will probably be completed by the end of spring 2000, and the swelling measurement will then give a good indication of the global behaviour under irradiation.

It has been planned that for the next RERTR meeting we will be able to have an idea of what the fuel test assemblies will be.

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