RERTR Program

# STATUS OF FRENCH REACTORS

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## ABSTRACT

The status of French reactors is reviewed. The ORPHEE and RHF reactors can not be operated with a LEU fuel which would be limited to 4.8 g U/cm$^3$. The OSIRIS reactor has already been converted to LEU. It will use $U_3Si_2$ as soon as its present stock of $UO_2$ fuel is used up, at the end of 1994. The decision to close down the SILOE reactor in the near future is not propitious for the start of a conversion process. The REX 2000 reactor, which is expected to be commissioned in 2005, will use LEU (except if the fast neutrons core option is selected). Concerning the end of the HEU fuel cycle, the best option is reprocessing followed by conversion of the reprocessed uranium to LEU.

## INTRODUCTION

To date, CEA operates a large number of irradiation facilities :

- 7 critical assemblies (MASURCA, EOLE, MINERVE...),
- 8 source reactors (HARMONIE...),
- 2 training reactors (ULYSSE, SILOETTE...),
- 3 special reactors for safety studies (CABRI, PHEBUS, SCARRABE),
- 4 research reactors (OSIRIS (+ ISIS), SILOE, ORPHEE, RHF).

The only facilities concerned by the RERTR program are the reactors which regularly, consume a large quantity of fuel, and namely ORPHEE, RHF, OSIRIS and SILOE. All the others have a very specific fuel or use only one core from the beginning until the end of their life.

ORPHEE - RHF

These two reactors are only used for basic research. It has been proved that they can not use a LEU fuel with a uranium content limited to 4.8 g/cm$^3$. These 2 reactors with the BR2 reactor located in Belgium are considered, at the present time, as an exception in the RERTR program because they will continue to use highly enriched uranium.

OSIRIS (+ ISIS)

In 1980, these reactors, which had used highly enriched uranium since they went into service in 1966, were converted to low enriched uranium (7.5 %). To reach a sufficient $U^{235}$ density with such a low enrichment, the fuel plates were made of a multitude of thin square fuel pellets of $UO_2$ called "Caramels".

In 1987, it was decided to standardize the manufacturing of fuels of the MTR reactors and thus to abandon, in the end, the manufacturing of $UO_2$ fuels to devote all development and qualification efforts to the silicide fuels.

To date, more than 200 $U_3Si_2$ fuel elements (4.8 g/cm$^3$) have been manufactured, representing three years of operation of the OSIRIS reactor.

To start the progressive change process, CEA is waiting until its entire stock of Caramel fuel elements is used up. The last Caramel elements will be put in during December of 1994, and thus the change will start in January of 1995.

The license to use $U_3Si_2$ to replace $UO_2$ was difficult to get. The safety analysis of the reactor had to be completely redone and, on that occasion, the use of computer codes qualified according to the quality assurance rules were a constant requirement of the safety authorities and the source of the main difficulties. To get license it has been necessary to make commitments to carry out rapidly specific irradiation experiments in order to provide additional answers :

- The first question regards the release of fission products in the event of a cladding failure. In the case of a cladding failure on a $U_3Si_2$ plate, how is it possible to be sure that it can be quickly detected ? How can the cladding failure detection system be calibrated in relation to the former fuel ? How does a cladding failure evolve (reaction with water...) ? To be able to provide precise figures to these questions, an irradiation called EPSILON will begin in

November 1994 in a loop of the SILOE reactor with an on-line measurement of the fission products release. Special miniplates with calibrated defects have been made with both $U_3Si_2$ and UAl alloys to make comparison.

The miniplates will be irradiated at different power levels.

The activity of the water will be continously measured by on-line gamma spectrometry, delayed neutrons detection, and by water sampling.

After irradiation each miniplate will be examined by various post irradiation examination such as metallographies (surface of the defect) and section gamma scanning (fission products distribution in the defect zone).

- Another question concerns the validation of the computer codes (thermohydraulics) in some incidental situations. A special fuel element with a plate equipped with thermocouples has to be made. Tests will be carried out with this element during one cycle of the reactor.

SILOE - SILOETTE

The principle of the conversion of the SILOE reactor was decided in 1989. But in 1993 it has been decided to shut down the reactor definitively in the near future without knowing exactly which year. The reason for the decision is not related to the age of the reactor, nor to the safety, but there are, in fact, fewer and fewer technological irradiation programs and it is not possible to ensure a sufficient work load for both OSIRIS reactor and SILOE reactor.

In this context, we do not think that we can start the planned process of conversion. We plan to continue until the end in burning old stocks of HEU which are available in France (in the range of 85 % to 90 %).

The closing of this reactor could constitute a serious problem for the R & D program on high density silicide fuels because research and development program has been implemented between CEA and CERCA to increase the quantity of $U^{235}$ per fuel element:

- by increasing the thickness of the fuel meat and by reducing correlatively the thickness of the cladding ;
- by increasing the uranium density from 4.8 to 6 g/cm$^3$ ;
- by a combination of these two parameters.

Since august 1994 an irradiation experiment has been in progress in the IRIS device to test the behaviour of the increase of the thickness of the fuel meat. The high density fuel plates will be loaded in this device early in 1995.

After closing down SILOE, this program will be probably cancelled because it will not be possible to move the irradiation devices in the OSIRIS reactor.

## REX 2000

CEA has decided to build on the site of the Centre d'Etudes in Cadarache a "multipurpose" reactor in the 50-100 MW range to replace the OSIRIS and SILOE reactors in the year 2005.

Three designs have been studied :

- a fast neutron core (plutonium) surrounded by a graphite reflector ;
- a RHF GRENOBLE type core, but using LEU,
- a traditional pool reactor (LEU).

The final choice will be made in 1995 on the basis of the needs of technological experiments, such as they can be anticipated today, over the next 30 years.

## FUEL CYCLE

The reprocessing is, in France, the reference process to manage the irradiated fuels. So that, all the irradiated fuels elements coming from OSIRIS reactor ($UO_2$ Caramels) will be reprocessed by the CEA in its MARCOULE plant (APM) in 1996 and 1997.

Concerning the HEU fuel elements, our intent is to mix the reprocessed uranium with depleted uranium to get LEU fuels. Because of the progress made by CERCA in 1994 to use uranium batches containing small amounts of transuranic elements and fission products, CEA is now very confident in the future. CERCA is in a position to ask license from the french regulatory body to use the LEU reprocessed uranium in the fuel manufacturing plant.

| Reactor | Type of fuel | Number or irradiated elements as of 7/10/94 | Location of elements as of 7/10/94 | Planned end of cycle |
|---|---|---|---|---|
| OSIRIS | $UO_2$ 7.5 % | 813 | - Reactor site<br>- PEGASE storage<br>- APM (Marcoule) | To be reprocessed in 1996 and 1997 at APM (CEA reprocessing facility in Marcoule) |
| | $U_3Si_2$ 20 % | 15 | - Reactor site | CASCAD dry storage (Cadarache) |
| SILOE | UAl 93 % (85-90 %) | 292 | - Reactor site<br>- PEGASE storage | Planned options<br>- Cogema reprocessing, $UP_1$ Marcoule<br>- AEA reprocessing → LEU 20 %<br>- Return US DOE<br>↓<br>Osiris<br>REX 2000 |
| ORPHEE | $UAl_x$ 93 % | 144 | - Reactor site<br>- PEGASE storage | |
| RHF | $UAl_x$ 93 % | 18 cores | - PEGASE storage | |
| REX 2000 | LEU (or Pu) | 0 | | CASCAD dry storage (Cadarache) |