A NEW MTR FUEL FOR A NEW MTR REACTOR: UMo FOR THE JULES HOROWITZ REACTOR

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ABSTRACT

Within some years, the Jules Horowitz Reactor will be the only working experimental reactor (material and fuel testing reactor) in France. It will have to provide facilities for a wide range of needs: from activation analysis to power reactor fuel qualification.

In this paper will be presented the main characteristics of the Jules Horowitz Reactor: its total power, neutron flux, fuel element... Safety criteria will be explained. Finally merits and disadvantages of UMo compared to the standard U_3Si_2 fuel will be discussed

1. Introduction

The Jules Horowitz Reactor is a new research reactor project dedicated to materials and nuclear fuels testing, the location will be at the CEA-Cadarache site, and the start up in 2010.

The main objectives of the JHR are:

to meet the utility needs:
- electricity generating cost improvement in a competitive environment (fossil fuel)
- safety improvement (present PWR plants, new PWR plants (EPR)...)

to carry out Irradiation programmes:
- burn-up improvement of UOX and MOX fuels up to 120 GWd/t for future reactor generation
- research on plant life extension
- development of new fuels / materials for other reactor types (BWR, HTR, FBR, ...)
- to continue the research on transmutation of actinides and long life fission products

to meet "associated" demands:
- activation analysis
- neutron radiographs
- radio isotope production...

The following topics will be approached:
- main parameters characterising the reactor (qualitative and quantitative aspects)

- design criteria
- comparison of the performances of the fuels U_3Si_2 (4.8 and 5.8 gU/cm^3) and UMo (8 gU/cm^3) used in the JHR

2. Parameters characterising the reactor

Flexibility (large range of performance)

Three cores are being designed:

- A big 300 litres core (330 kW/l), close to Osiris performance, able to accommodate many experiments which do not need very high flux,
- A small 133 litres core (750 kW/l) able to irradiate a small number of fast neutron experiments,
- The reference 166 litres core (600 kW/l) can produce a flux almost twice the Osiris flux. In this core almost all the experiments can be carried out except experiments needing a fast accumulation of damage.

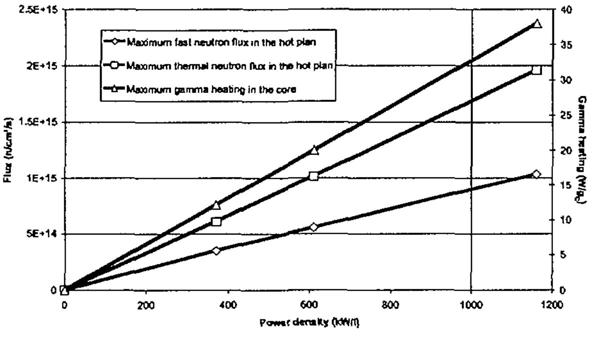

Figure 1 - Flux and gamma heating

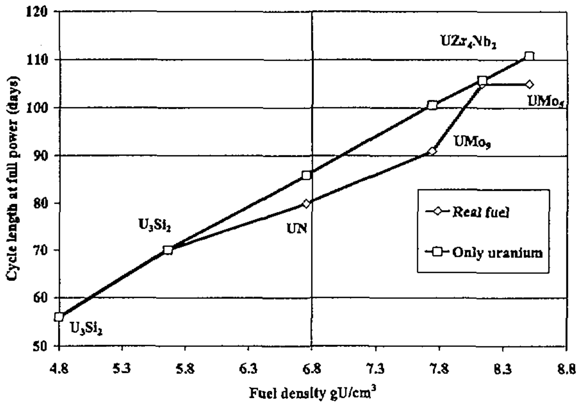

Figure 2 - Cycle length vs fuel density

Quality of experiments

Much attention will be paid to experiments quality. Are currently under development:

- R&D on new refabrication methods,
- R&D on new sensors (e.g. on-line pressure measurement with possibility of intermediate recalibration),
- on-line fission gas analysis,
- R&D on new non-destructive methods (X tomography, gap measurement, quantitative gamma spectrograph, pressure measurement...),
- R&D on gamma shielding to protect irradiation devices in the reflector AND in the core

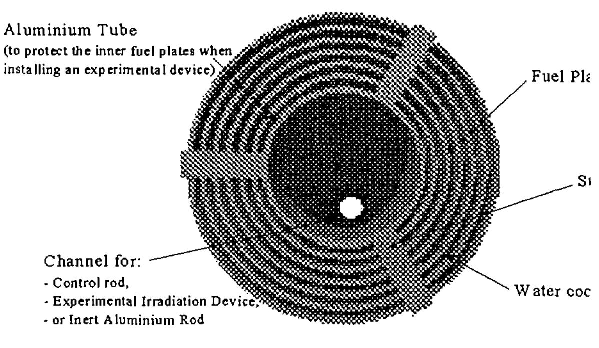

Figure 3 - Standard Fuel Element

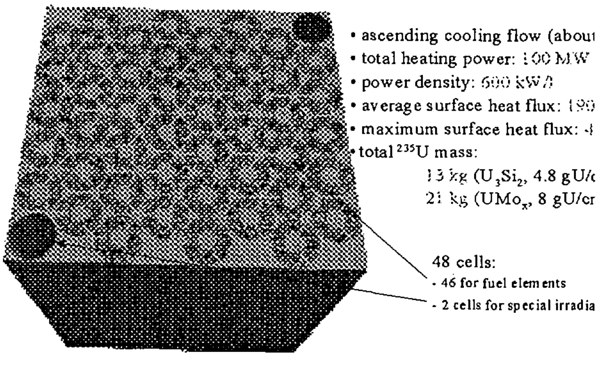

Figure 4 - Reference RJH Core (166 l)

Main quantitative characteristics

Total thermal power	100 MW
Power density	600 kW/l (reference)
Expected neutron flux	1.10^{15} n/cm²/s (E < 0.625 eV) 5.10^{14} n/cm²/s (E > 0.907 MeV)
Core inlet temperature	30°C
Mean core outlet temperature	50°C
Reflector	Be and water
Fuel enrichment (^{235}U)	20%
Fuel	U_3Si_2 -Al (4.8 gU/cm³) (reference) UMo -Al (8 gU/cm³)
Fuel element	Assembly of curved plates maintained by stiffeners (cylindrical element: see Figure 3)
Core	Triangular lattice, the fuel elements are within a rack machined in a block of aluminium (Figure 4)
Primary circuit	Closed (« real » second barrier) Slightly pressurised (approximately 0.5 MPa at outlet core) Ascending cooling flow (transition to natural convection realisable without active water injection system). See Figure 5.

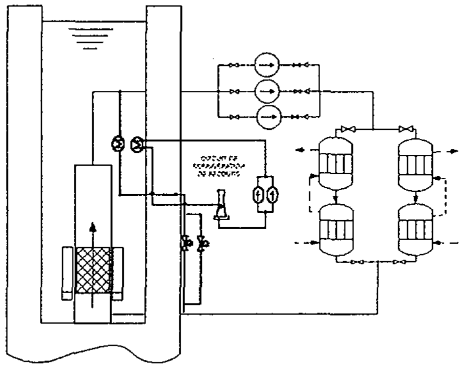

Figure 5 - Primary circuit

3. Design criteria

Thermohydraulics

To ensure the first barrier integrity it is thus necessary to cool the fuel in any situation (nominal power and normal and accidental transient).

During normal operation situation (up to 110% of the nominal power and 90% of the nominal primary flow: extreme case of normal operation), the criteria to be met are:

- $T_{wall} < T_{sat}$(hydrostatic pressure) + ΔT_{sat}(hydrostatic pressure) −10°C
  (to prevent any boiling in the event of depressurisation)
- $T_{cladding} < 150°C$
  Beyond 150°C, mechanical behaviour of the cladding (composed of an aluminium alloy) is degraded. To ensure the maintenance in the time of the coolant channels thickness, the cladding temperature is limited to 150°C.

During a loss of flow transient, the cooling must be ensured. The following criterion must be met:

- $T_{wall} < T_{sat}$ (nominal pressure) + ΔT_{sat}(nominal pressure)
  (the case of a simultaneous loss of pressure is not considered)

These criteria lead to a nominal primary flow of 1700 kg/s with the following temperatures (Figure 6):

- $T_{wall\,max} = 141°C$
- $T_{meat\,max} = 173°C$ (U_3Si_2, 4.8 gU/cm³: $\lambda = 30$ W/m/K)

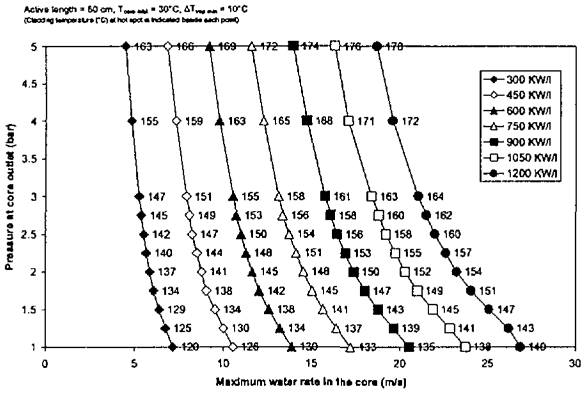

Figure 6 - Pressure - maximum water rate in the core (with safety margins)

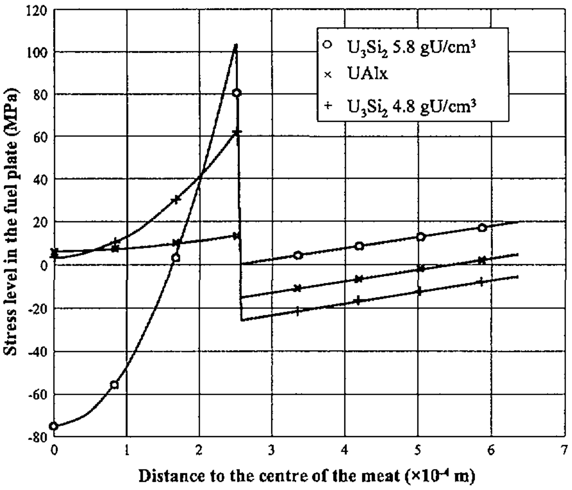

Figure 7 - Stress level in the fuel plate

4. Comparison U_3Si_2 –UMo

Fissile load

The original weight of ^{235}U in the core is:

U_3Si_2 (4.8 gU/cm^3): 13 kg
U_3Si_2 (5.8 gU/cm^3): 16 kg
UMo_8 (8 gU/cm^3): 22 kg

A unique batch fuel management is almost mandatory to meet the minimum cycle length with U_3Si_2 (4.8 gU/cm^3). A half core reload management is possible with UMo and U_3Si_2 (5.8 gU/cm^3).

Composition

	Fissile powder volume fraction	void	aluminium
U_3Si_2, 4.8 gU/cm^3	43.2%	8.5%	48.3%
U_3Si_2, 5.8 gU/cm^3	52.1%	15.0%	32.9%
UMo_8, 8 gU/cm^3	51.2%	≈ 10%	≈ 38.8%

Gamma heating

The maximum gamma heating in core for U_3Si_2 is close to 20 W/g$_C$.

For UMo, gamma heating should be lower because the gamma self-absorption is larger due to the higher density of UMo.

Cycle length evaluated without irradiation device

The cycle length of a core loaded with U_3Si_2 fuel (4.8 gU/cm^3), is 55 days. With U_3Si_2 fuel (5.8 gU/cm^3), this length goes up to 70 days. For UMo (8 gU/cm^3), it should be about 100 days (Figure 2). These cycle lengths must not be considered as absolute values: they are only indicated here as a relative comparison element.

Reprocessing ability

Reprocessing of U_3Si_2 fuels is not available on an industrial scale in current facilities [2].

On the opposite UMo reprocessing feasibility is proven [3]. Dissolution is the key processing step. Dissolution behaviour of UMo meat was already checked satisfactorily in a series of preliminary tests [3]. After dissolution UMo liquor is diluted into LWR dissolution solutions and the impact of UMo on the next process steps is hence easily manageable. The slight increase of Mo in fission products is deemed to have no significant effect on the vitrification process so that the internationally approved specifications of the vitrified fission products are met.

UMo can be easily reprocessed in the reprocessing plants.

Manufacturing

U_3Si_2 powder is obtained by a mechanical process: crushing U_3Si_2 alloy.
The UMo powder is manufactured by dispersion of UMo liquid jet.

The general process for making UMo plates is not fundamentally different from the U_3Si_2 process. The advanced process used for high densities (6 gU/cm³) in U_3Si_2 has been improved to reach 9 gU/cm³ with UMo [4].

Thermomechanical properties

U_3Si_2 (4.8 gU/cm³) conductivity is about 30 W/m/K [1]. U_3Si_2 (5.8 gU/cm³) conductivity is about 10 W/m/K [1].

Because of the level of performance (power density) of the JHR, using U_3Si_2 5.8 gU/cm³ would lead to fuel plates stress level higher than in any existing experimental reactor. Thus this option has been abandoned (see Figure 7).

5. Conclusion

Studies are going on. Precise evaluation of cycle lengths and performances of cores loaded with U_3Si_2 and UMo fuel are not available at present time. But they will be presented during oral presentation at RRFM 2000.

U_3Si_2 5.8 gU/cm³ option has been abandoned due to its low thermal conductivity.
U_3Si_2 4.8 gU/cm³ is the JHR reference fuel.
UMo_x 8 gU/cm³ will become the reference fuel as soon as it is qualified.

6. References

[1] Safety Evaluation Report related to the Evaluation of Low-Enriched Uranium Silicide-Aluminium Dispersion Fuel for Use in Non-Power Reactors – NUREG 1313
[2] Research Reactor Fuel Management, J. Thomasson, RRFM 99
[3] Technical Ability of New MTR high density Alloys Regarding the whole fuel cycle, J-P. Durand, B. Maugard, A. Gay, RRFM 98
[4] LEU Fuel development at CERCA, status as of October 1997, Preliminary developments of MTR plate with UMo fuel, J-P. Durand, Y. Lavastre, M. Grasse, RERTR 1997, Jackson Hole