Jules Horowitz Reactor
Il ruolo di JHR per lo sviluppo dei reattori di IV Generazione

Test devices under feasibility study – towards GEN IV

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**JHR experimental capacities**

**General characteristics**

**In reflector**

- Up to $5.5 \times 10^{14}$ n/cm$^2$.s
- ~20 fixed positions ($\Phi 100\text{mm}$; 1 position $\Phi 200\text{mm}$) and 6 displacement systems

**In core**

- Up to $5.5 \times 10^{14}$ n/cm$^2$.s > 1 MeV
- Up to $10^{15}$ n/cm$^2$.s > 0.1 MeV

- 7 Small locations ($\Phi \sim 32\text{ mm}$)
- 3 Large locations ($\Phi \sim 80\text{ mm}$)

**GEN IV Fuel studies:**

- Short term irradiation (off-normal conditions; Na)
- Analytical irradiations

**Material ageing**

- Low ageing rate

**Material ageing**

- Up to 16 dpa/y (High n flux - high $\gamma$ heating)

**Fuel experiment**

- (Fast neutron flux)
- Long term irradi.; NaK Neutron filters (thermal flux)

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**Illustration of nuclear power evolution in France**

- Generation 3
- Generation 4
- Plant life extension beyond 40 years
- Existing technologies (PWR, BWR, ...)
- Generation 4

**GW**

- 1980
- 1990
- 2000
- 2010
- 2020
- 2030
- 2040
- 2050
- 2060

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**Thermal neutron flux**

**Fast neutron flux**
First exemple : clad material evolution from GEN 3 to GEN 4

Gas cooled reactor (Gen 4)
Cladding material : SiC or refractory metal

Operating conditions :
- Temp.: 1000/1200°C
- Helium 7MPa
- Stresses (fuel clad interact.)
- Irradiation (fast neutron flux => high ageing rate)

Sodium cooled reactor (Gen 4)
Cladding material : stainless steel

Operating conditions :
- Temperature 400 / 550°C
- Sodium
- Stresses (fuel clad mechanical interaction ; fuel swelling)
- Irradiation (fast neutron flux => high ageing rate 130 dpa to 200 dpa with ODS ?)
- Clad Inner side Corrosion (FP)

Light Water reactor ; cladding material : Zr alloys

Operating conditions :
- Temperature 300 / 320 °C
- Water + additives (corrosion : oxydation and hydriding)
- Stresses (water pressure 15MPa , fuel clad mechanical interaction)
- Irradiation
- Gen 2 and 3 : mastered technology – very accurate experimentation
Second exemple : The fuel

Present fuel (UO2 ; UPuO2) :

Various μstructures (UO2, MOX) and evolutions (additives, grain size,…)

μstructure evolution due to irradiation (fg release, rim, …)

Needs : knowledge about fg release under normal and off-normal conditions, mitigate PCMI impact during power transients, knowledge about fuel behaviour under accidental conditions…

Fuel evolutions :

new materials : (UO2-MOX), U Pu C or U Pu N,
minor actinides
new fuel concepts ; new μstructures
**Hosting experimental systems under feasibility studies**

- High temp. material irradiation (600-1000°C)
  - Large capacity

- MICA (material irrad) adapted to 1000°C gas conditions (Phaeton type – Osiris technology)

- LORELEI fuel testing under accidental conditions (LOCA)

- Transmutation studies

- CALIPSO adapted to SFR fuel and material
  - Normal => in core
  - Off normal => in reflector

- Corrosion loop for Zr alloy corrosion and IASCC

- Other topics
  - LWR: Adeline « FP »; Adeline “power to melt”; severe accident studies
  - GFR: fuel irradiation (normal and off-normal conditions)
  - Fuel characterization: basic properties under irradiation (thermal diffusivity, thermal creep...)

ROMA seminar – November-10th 2011
JHR capabilities to investigate phenomena connected to the transmutation (Th Stummer PhD)

Test device concept = Diamino test device (Osiris)

For example : simulation of the fuel damaging phenomena (He release, irradiation and FP impact) by adjusting U and Am contents (but with the same µstructure) in a sample irradiated in the JHR reflector.
CALIPSO: Irradiation at controlled temperature, at low pressure, under high flux (under forced NaK convection)

- Present design: Material irradiation
  - In-core material irradiation, high ageing rate; $T = 250$ to $450^\circ C$ (LWR)
- Next step (1): Material irradiation
  - In-core material irradiation,
  - High ageing rate;
  - Temp. up to $650^\circ C$ (liquid metal FR)
- Next step (2): Fuel irradiation
  - Fuel samples irradiation SFR conditions
    - In-core: long term irradiations (NaK-filters)
    - In-reflector: off-normal situations, power and flowrate transients (Na)
    - Clad failure detection (gas sampling line; FG release)
  - Fuel samples irradiation Pb-Bi FR conditions
Calipso: evolution for SFR material and fuel irradiation

Preliminary calculation – SFR fuel application
Present design + capsule

FUEL - Capsule

Preliminary calculation – SFR fuel application
Adapted design (guide tube, flowrate)

FUEL – « direct cladding cooling »

MATERIALS

Preliminary calculation – SFR material application
Adapted design (guide tube, flowrate)
Calipso
Evolution for SFR fuel irradiation
Neutron screens

ROMA seminar – November-10th 2011
High Temperature, instrumented, material Irradiation

Test device: Phaeton type - Osiris technology (Chouca-He)
Example: Tests on SiC fibers performed in Osiris reactor at ~1000°C (Cedric – Crocus experiments)
High temperature material irradiation

- Test device devoted to material testing at high ageing rate and high temperature (600-1000°C, liquid metal FR & GFR)
- Use of a “gas loop technology” (helium natural convection or forced convection)
- Large capacity (numerous samples - 6x20); in-core large location
Conclusion

The JHR design allows to investigate GENIV phenomenology (materials and fuels)

Very preliminary conceptual designs studies were carried out for SFR fuel and material irradiation (taking benefit of the “Calipso technology”)
These preliminary designs have to more deeply investigated

Neutron screens is still an issue

Adaptation to Pb-Bi technology has to be done

GFR technology is an almost non-explored domain