The PHEBUS facility and related studies

OUTLINES

- Context

- PHEBUS FP Programme and FPT3 test

- PHEBUS Facility description
  - Reactor
  - Fission Products Lab

- Main characteristics for other experiments
PHEBUS is a research reactor operated by CEA at the Cadarache research centre

Since its operational start, PHEBUS has been dedicated to safety issues experiences in order to:

- Achieve integral experiences to improve the knowledge in case of incidental conditions and severe accidents consequences
- Validate calculation codes through global experiences

At the present time, the arising question concerns the future programs to be carried out in PHEBUS.
History:

- 1979: Operational start of the PHEBUS facility reactor
- From 1979 to 1990: programmes LOCA, SDC
- 1990: Operational start of the FP Laboratory. Global seism reinforcement.

While achieving international programmes managed by IRSN, the PHEBUS facility has allowed a better understanding of core degradation modes and fission products release.
The international PHEBUS FP Programme reproduces (on a reduced scale 1/5000 vs 900 MW PWR) a core meltdown accident in a P.W.R.
Fuel Re-irradiation

Transition phase

Expérimental phase

8 days

36 h

5 hours
FP Programme main improvements:

⇒ The core degradation, corium relocation and corium formation,
⇒ The hydrogen production by oxidation during core degradation,
⇒ The nature and quantities of radioactive products released to the environment

The PHEBUS FP test matrix:

- FPT0 (1993)
- FPT1 (1996)
- FPT4 (1998)
- FPT2 (2000)
- FPT3 (2004)
- FPT5 => STLOC1 postponed to 2012
PHEBUS facility

FP LAB & Containment vessel

PHEBUS Reactor
PHEBUS reactor

PHEBUS is a (max) 38 thermal MW pool type reactor
During several days, 20 MW operating can be carried out

Main components

– A driver core dedicated to produce the neutron flux in order to:
  • Create short life fission products in the experimental fuel
  • Bring to the experimental fuel the representative nuclear heating

– A specific in pile pressurized water loop (155 b, 320 °C) dedicated to experimental fuel settlement, re-irradiation and degradation.

– A leaktight cell, located vertically at the reactor core centre, in which takes place the experimental fuel device.
The PHEBUS reactor building also includes renewed tools such as:

- A 250 kN handling crane (heavy maintenance in 2004),
- A specific experimental device handling machine (control refurbishing in 2004)
- An immobilizing matrix injection equipment
- Storage pools
- An examination and control Equipment (tomographs and radiographs)
The PHEBUS FP lab was erected in 1990. It mainly contains:

- An *instrumented containment vessel* (350 m³) to receive the fission products released during the experience.

- Hot cells dedicated to experimental samples retrieval, gamma spectrometry measurement, conditioning and storage.
Different options are possible for the future of the PHEBUS facility:

- PHEBUS ST-LOC

At the present time, an international expert group is studying safety experiences that could require the PHEBUS facility tools

- Long term care and maintenance Program

- Other experimental issues based on the facility capabilities
**Conclusion : Experimental capabilities**

- A pressurized water loop reproducing PWR chemical, thermal and hydraulics conditions (until 160 bar and 320 °C)
- Experimental cell on the core vertical axis: Axisymmetric neutron flux
- Adjustable Cooling flowrate (until 90 m$^3$/h)
- Large Experimental cell diameter (124 mm)
- Driver core active height of 80 cm
- Power reserve allowing the neutronic spectrum adjustment for the experimental test device design
- Highly skilled operators and revamped equipment
- The design and safety requirements of the PHEBUS FP programme allow a large experiences panel in the facility
The PHEBUS reactor at work: FPT3 test, November 18, 2004

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Driver core and pressurized water loop
PHEBUS: an international objective

The Phebus network gathers more than 40 international institutes.

+ Bulgarie, Hongrie, République Tchèque, Roumanie, Slovaquie, Slovénie
PHEBUS FPT3 test

FPT3 Degradation phase (18/11/2004). General chronology

- Start oxidation runaway: 14:33
- Start steam starvation: 14:36
- Start heat up phase: 16:06
- Shut-down: 16:38
- Duration heat up phase: 00:32

- Start P4: 14:54
- Activate criteria: 16:02
- End P4: 16:06
- Duration P4: 01:12

- Start relocation

Fuel - 300mm
Shroud - 100 mm - 170°
Shroud - 100 mm - 349°

Clad burst

B₄C CR burst

Time (H:M:S)

Temperature (°C)

Core power (MW)
• 36 Fuel elements with a 2.78% enrichment in $^{235}$U

• 6 safety control rods (hafnium)

• 4 barriers between the experimental fuel and the pool water

• Graphite reflectors layers
**PHEBUS containment vessel dismantling**

**Required operations**

- Liquid decontamination
- RC Dismantling
- Final dismantling and clean-up
- Active waste transfer
- Samplings preparation and gamma measurement
- Samplings retrieval
- Samplings storage

*Vessel*

- CECILE
- DEDA
- CELENA
FPT3 main events

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1580°C
1400°C
Tg = 700°C

P4 [obj. 2000°C max]

Start relocation

Core power (MW)

Temperature (°C)

Fuel - 300mm
Shroud - 100 mm - 170°
Shroud - 100 mm - 349°

Clad burst

B4C CR burst
Positions des BCS

Bras anti envol

Pilotage dégradation sur 4 BCS

HN1
HN2
HN3
G2.1
G2.2
HN1
HN2
HN3
G2.1
Instrumentation boîtier
STLOC Programme:
- Restricted experimental objectives
- PF LAB vessel required simplified manual interventions

PHEBUS ST-LOC : The test matrix consists in five experiments
- 3 «FP» type
  - High Burn-Up (52 -- 70 GWJ/T)
  - MOX
  - Quench

- 2 LOCA type (with irradiated fuel)
  - MOX and High Burn-up
PHEBUS FP lab

The PHEBUS FP lab also includes several equipment in order to deal with:

- Solid waste
  - They are transferred outside the vessel through a device assuming containment and radiological shield.

- Liquid waste
  - They are transferred out of the PHEBUS facility using a transport truck equipped with a double containment liner tank.