DE LA RECHERCHE À L'INDUSTRIE

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IGORR18 / IAEA meeting

Findings and results of safety reassessments and safety improvements on the ORPHEE research reactor

Focus on external hazards

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FINDINGS AND SAFETY IMPROVEMENTS FROM SAFETY REVIEWS

1. Presentation of the reactor
2. Findings of the periodic safety review
3. Findings of the post Fukushima stress tests
4. Focus on seismic related safety improvements

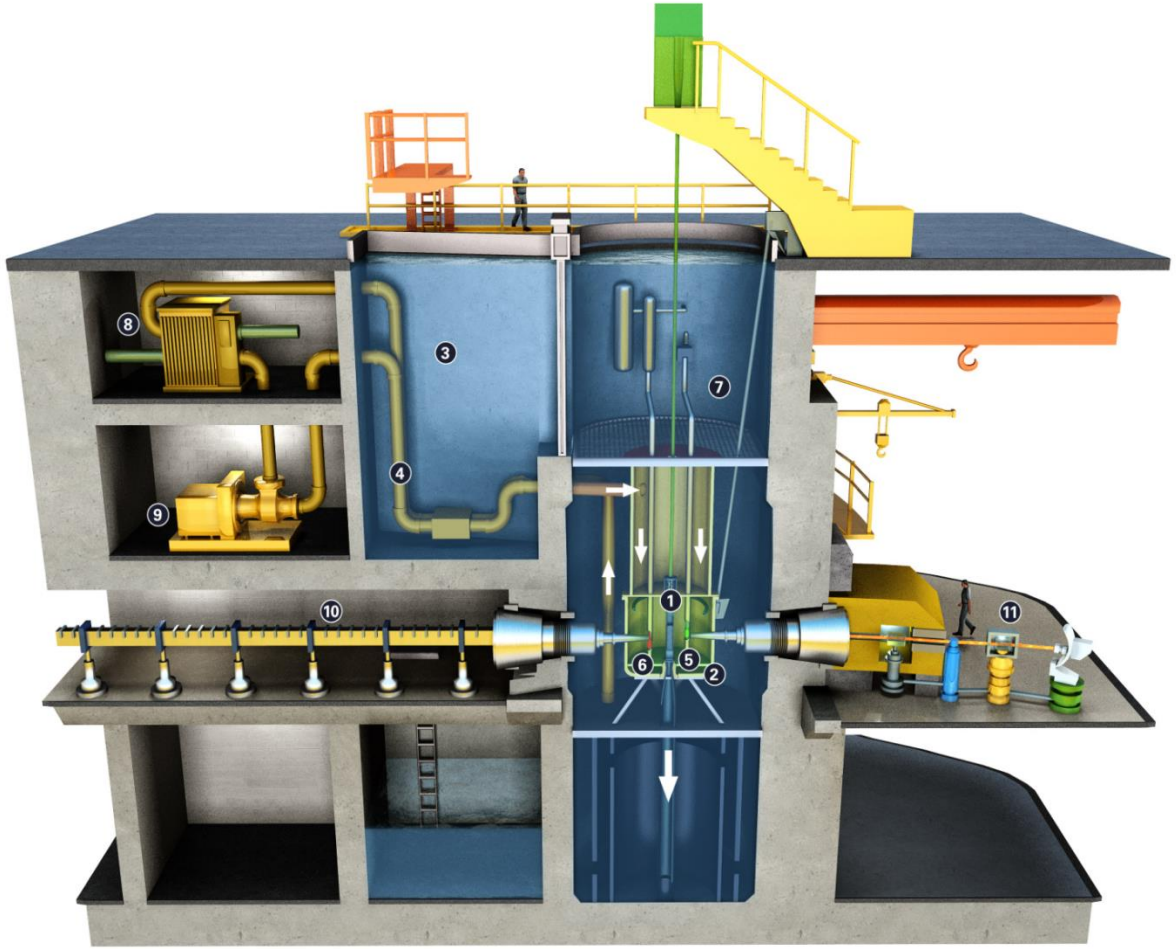
PRESENTATION OF ORPHEE REACTOR

Mission of the reactor: Supply neutron beams for fundamental research

- Reactor in operation since 1980, one of the 3 main neutrons flux reactors in Europe (HFR (ILL) in France and FRM-II in Germany)
- Operated by CEA
- Researchers: CEA/CNRS
- Industrial applications: silicon doping, radioisotopes production, neutron radiography

PRESENTATION OF ORPHEE REACTOR

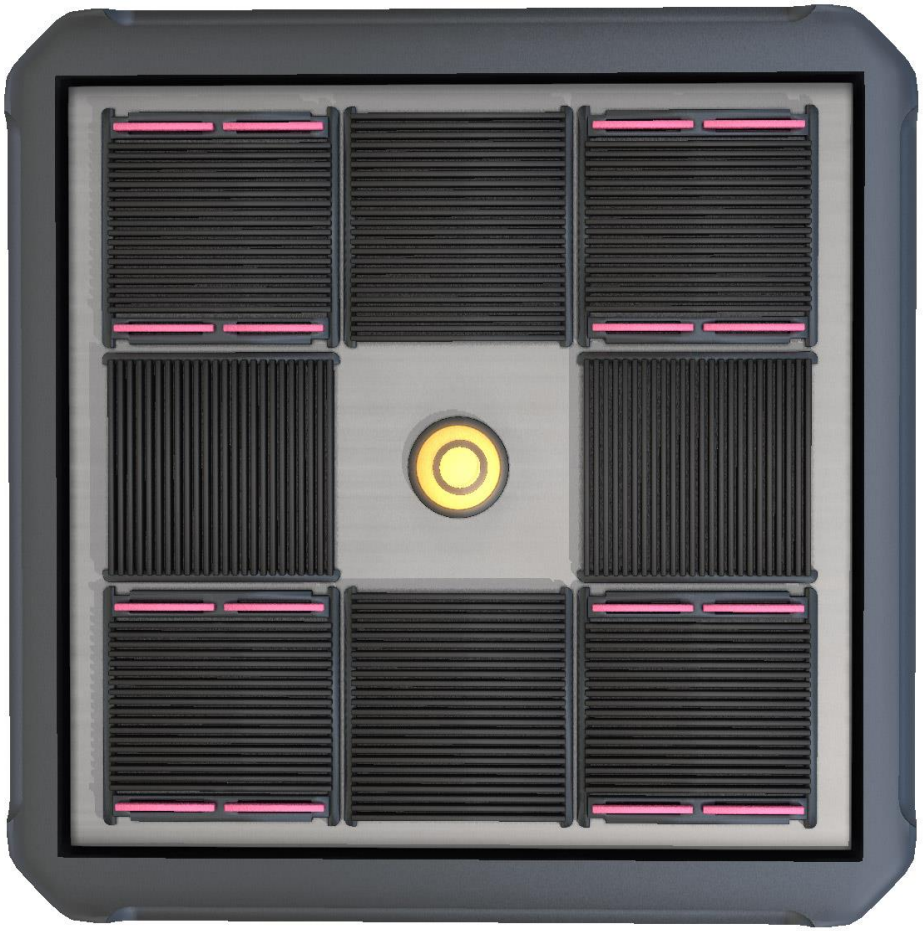
Vertical cut of the reactor core



1. Core
2. Heavy water reflector
3. Transfer canal
4. Primary cooling system
5. Hot Source
6. Cold source
7. Pool
8. Heat exchanger
9. Pump
10. Neutron guide
11. Spectrometer

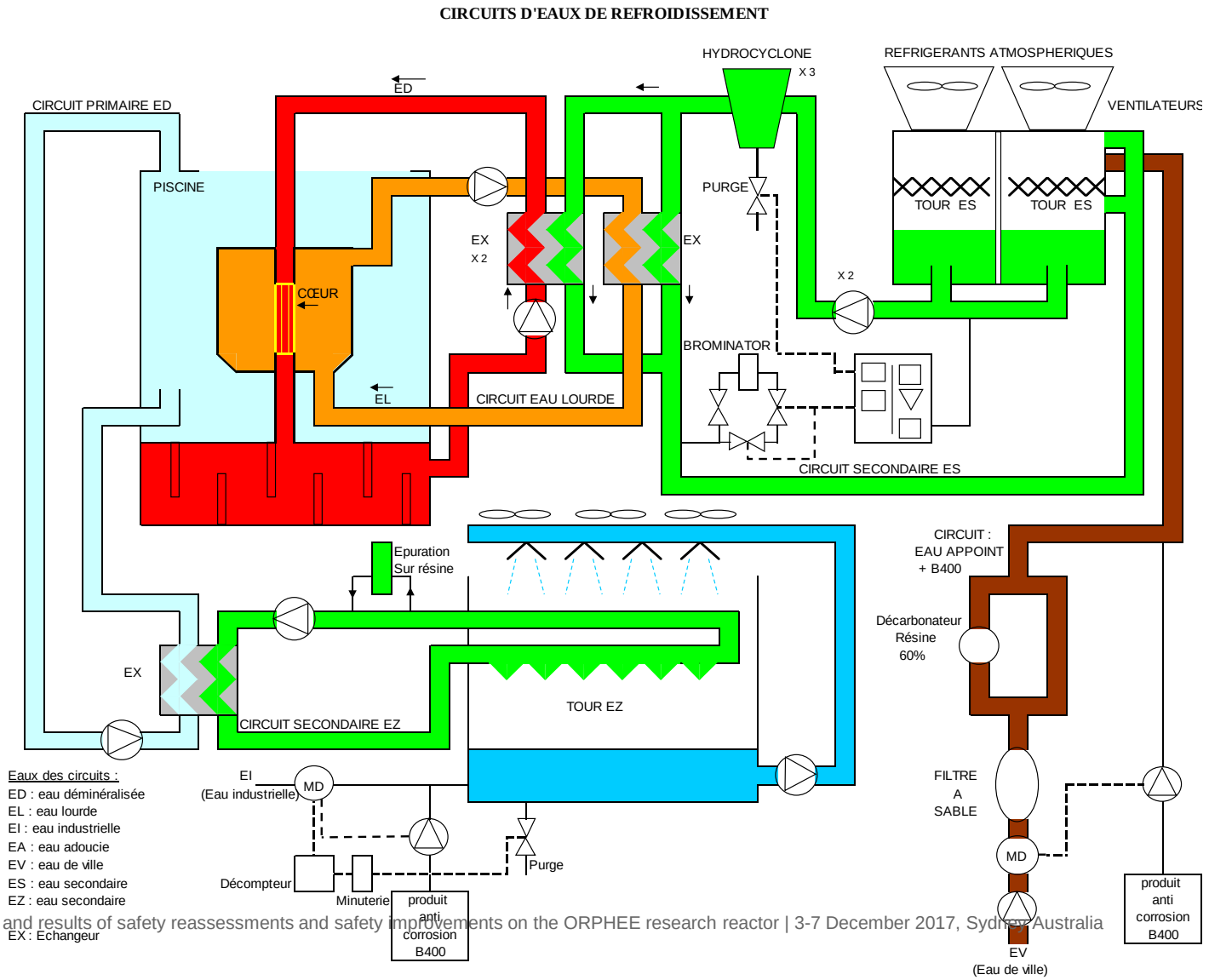
PRESENTATION OF ORPHEE REACTOR

The core



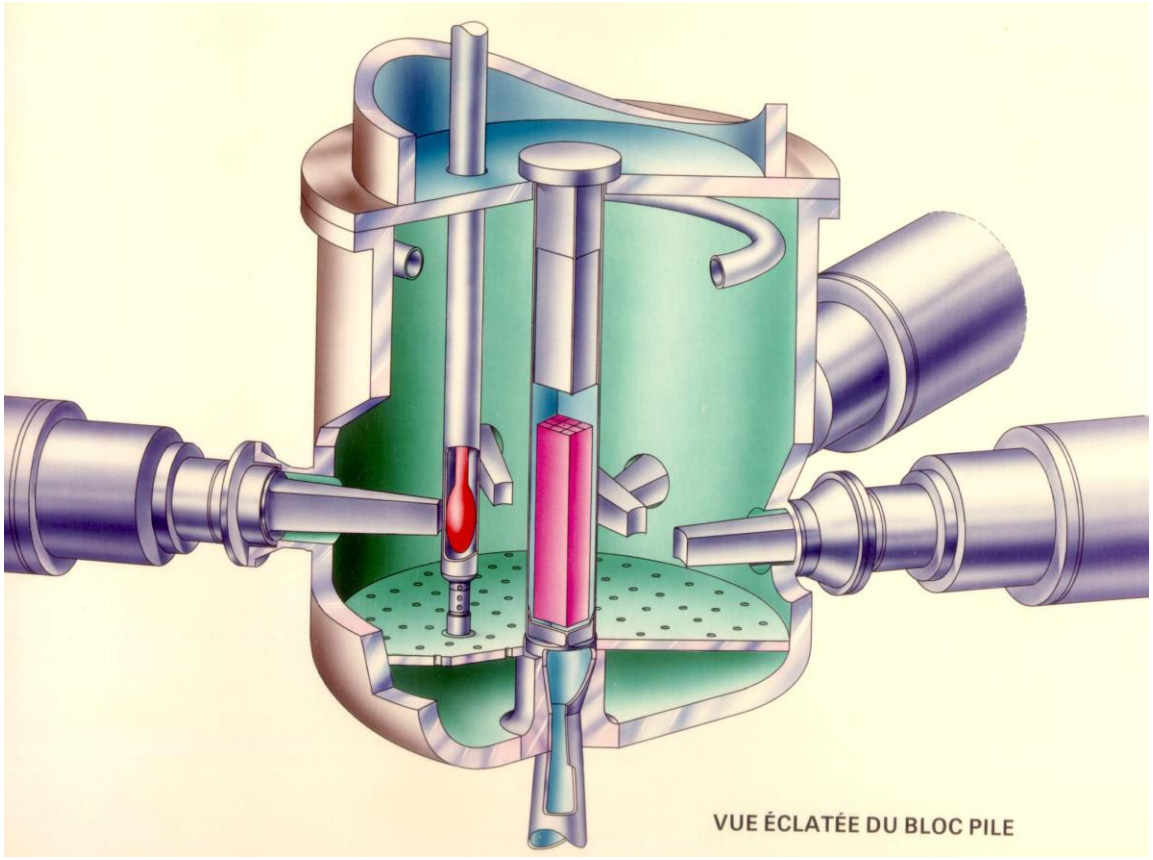
PRESENTATION OF ORPHEE REACTOR

Cooling systems



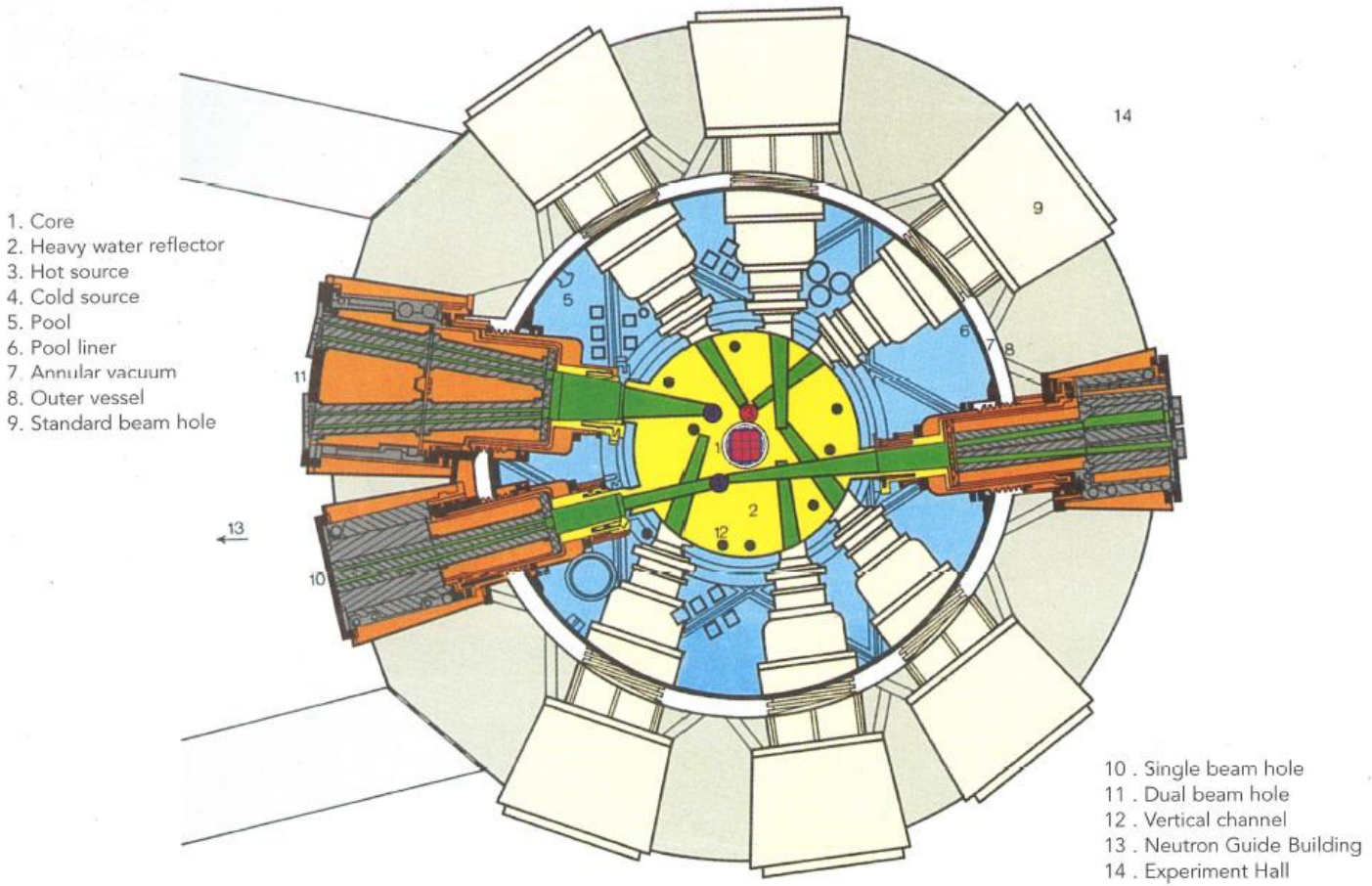
PRESENTATION OF ORPHEE REACTOR

Neutron beam tubes



PRESENTATION OF ORPHEE REACTOR

Location of experimental devices



SAFETY REVIEWS – ORPHEE REACTOR

Periodic Safety reviews since 1980

- 1st criticality of ORPHEE reactor : december 1980
- 1st safety review : december 1997
- 2nd periodic safety review : march 2009
- Ongoing 3rd periodic safety review : due march 2019

Stress tests after Fukushima accident

- Complementary safety studies (ECS) : June 2012

FINDINGS OF THE SECOND PERIODIC SAFETY REVIEW (2009)

1. ***Methodology***
2. ***Overall conclusion***
3. ***Focus on findings related to seismic effects***

FINDINGS OF THE SECOND PERIODIC SAFETY REVIEW (2009)

Methodology

- Continued operation of the reactor
- Operating experience of research reactors, lessons learned
- Conformity analysis
- Safety reassessment

FINDINGS OF THE SECOND PERIODIC SAFETY REVIEW (2009)

Overall conclusion

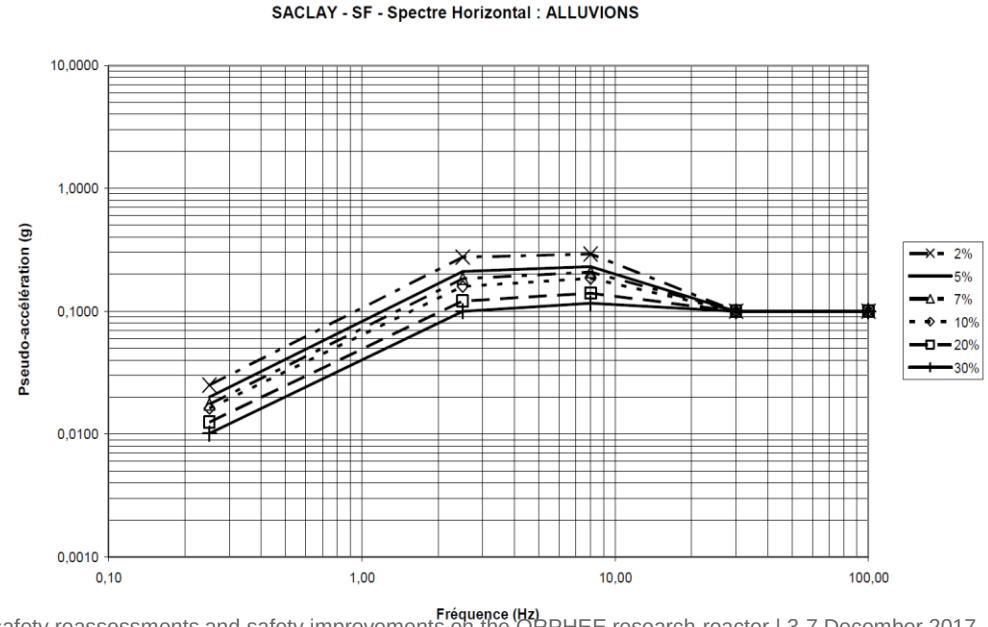
- The conformity analysis shows
  - An overall good conservation status of the utility
  - A few minor non conformity required corrections
    - polar crane,
    - civil work,
    - fuel storage racks,
    - piping supports
- Main evolutions in safety reassessment
  - Analysis of the operating situations (graded approach)
    - Implementation of a reactor trip in case of loss of heavy water cooling system
  - Internal and external hazards
    - Improve the protection of the utility against the effects of fire, flooding and lightning
  - Organisational and Human Factor
    - Procedures and material improvements, especially for fuel handling operations

FINDINGS OF THE SECOND PERIODIC SAFETY REVIEW (2009)

Focus on findings related to seismic effects

The CEA site of Saclay is located in a low seismicity area.

- Design of the reactor (late 70's)
  - Based on a maximal security seism (SMS) ranged at 0,025g (NRC Reg. Guide 1.60)
- PSR in 2009: higher intensity seism
  - The reference seismic response spectra for the site of Saclay are taken from the applicable safety rule RFS 2001-01, ranged at 0,1g (SF = *séisme minimal forfaitaire*)



FINDINGS OF THE SECOND PERIODIC SAFETY REVIEW (2009)

Focus on findings related to seismic effects

- PSR in 2009: RFS 2001-01, ranged at 0,1g (*séisme forfaitaire SF*)
  - Verification of the capability of te reactor to reach and maintain safe state:
    - the capacity of the control rods to drop and shutdown the reactor
    - the operability for opening of the natural convection check valves
    - the integrity of main piping of the primary cooling system
    - the civil work of the containment building, internal structures, heavy water building
  - As a conclusion: limited weaknesses identified on polar crane and fuel storage racks

FINDINGS OF THE POST FUKUSHIMA STRESS TESTS (2012)

1. Methodology

2. Main findings of the complementary safety studies

3. Findings and Conclusion

FINDINGS OF THE POST FUKUSHIMA STRESS TESTS (2012)

Methodology

- At the request of the french nuclear safety authority (ASN):
  - Assessment of the robustness regarding the considered extreme external hazards and postulated losses of electrical power supply and heat sink
  - Identify possible weaknesses that could possibly result in cliff effect, and determine margins

- Identifiy and define events likely to result in a risk of cliff effect
  - dewatering of fuel assembly (loaded in the reactor or stored in the pool)
  - ruin of the containment coupled with radioactive products release

FINDINGS OF THE POST FUKUSHIMA STRESS TESTS (2012)

Methodology

- Identify essential structures systems and components (SSCs) to reach and maintain safe state:
  - Shutdown of the reactor
  - Maintain the cooling of the core and spent fuel
  - Maintain containment
  - *And equipment for monitoring safe state*
- Evaluate the existing margins in extreme external hazard situations:
  - Seism
  - Strong wind and snow
  - Heavy rain and flooding
  - Lightning
  - Hail
- In the end, define a set of SSCs, so called *« hard core »*, aiming at
  - Prevent cliff effect in the radiological of an accident
  - Allow the crisis management in extreme situation

FINDINGS OF THE POST FUKUSHIMA STRESS TESTS (2012)

Main findings of the stress tests – seismic related

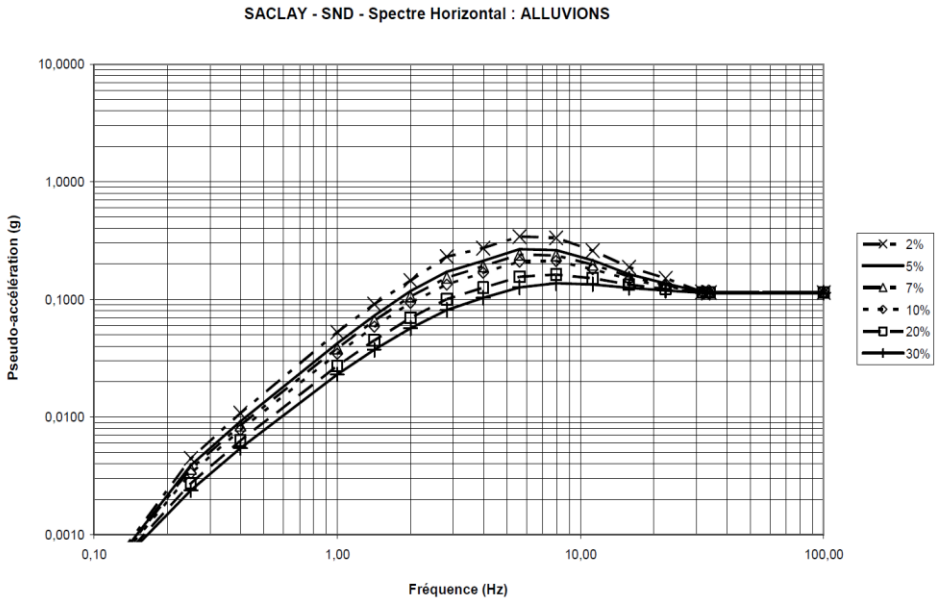
- Results of the margin evaluation for the main SSCs

Safety function	Equipment	Seismic margin (times SF)
Reactivity control	gravity control rod drop	2.0
Cooling	natural convection check valves	4.0
	civil work internal structures of the pool and transfer canal	2.3
	reactor and support	1.7
Containment	reactor building	2.0
	heavy water building	1.6
	reactor chimney	1.3
	ventilation building	1.3
	safeguard ventilation system	1.5

FINDINGS OF THE POST FUKUSHIMA STRESS TESTS (2012)

Main findings of the stress tests – seismic related

- Extreme seism for the site of Saclay *« hard core seism »* (SND)



- The extreme seism SND is envelopped by:
  - 1,0 times the SF for f < 4,1 Hz
  - 1,3 times the SF for f > 4,1 Hz

FINDINGS OF THE POST FUKUSHIMA STRESS TESTS (2012)

Verification to the SND of:

- the robustness of the reactor (support, core housing, heavy water tank, cooling channel)
- the leak tightness of the pool liner

Cumulative seism and seismic induced event

- The cumulative effects of a seism with the risk of flooding induced by an earthquake do not lead to an increased risk of cliff effect

Other extreme situations

- The risk assessment of flooding and extreme weather does not indicate any risk of cliff effect
- In the situation of loss of power supply or loss of heat sink
  - the Orphée reactor takes advantage of large reserves of water (reactor pool, transfer canal)
  - No risk of cliff effect is identified

SAFETY IMPROVEMENTS
FOCUS ON SEISMIC RELATED IMPROVEMENTS

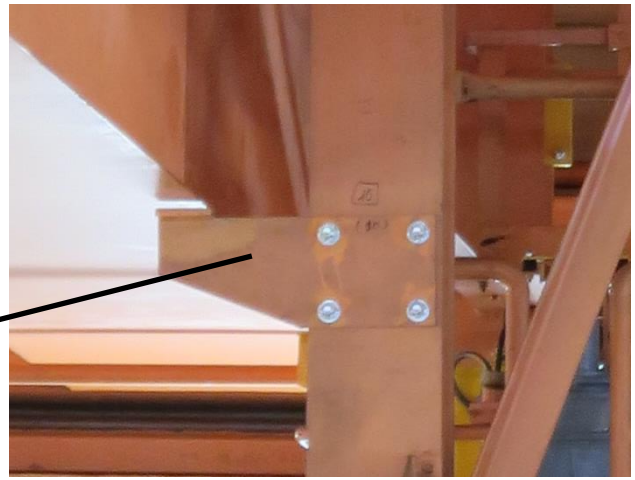
1. Improvements issued from the periodic safety review

2. Improvements issued from the stress tests

PERIODIC SAFETY REVIEW
SEISMIC RELATED SAFETY IMPROVEMENTS

Reinforcement of the polar crane

- Verification of the bolted structures
- Mechanical studies have shown limited weaknesses
- Safety margins were consolidated : replacement of bolts with higher class material (anti-lifting devices, counterweights, vertical uprights)



PERIODIC SAFETY REVIEW
SEISMIC RELATED SAFETY IMPROVEMENTS

Reinforcement of the fuel storage racks

- Fresh fuel storage racks: reinforced to prevent tilting in case of a seism
- Underwater spent fuel storage racks: reinforced to compensate missing bolts

Reinforcement of the battery racks

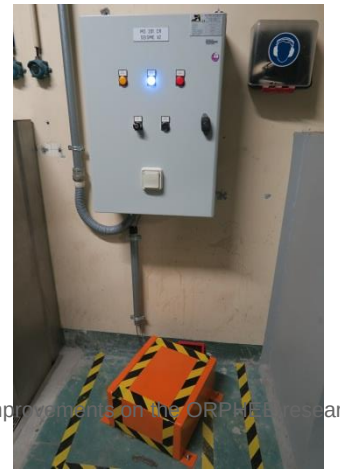
- Maintain stability and operation of batteries after a seism
- For security and backup control panel

STRESS TESTS
SEISMIC RELATED SAFETY IMPROVEMENTS

Reactor trip on the detection of a seismic event

- threshold set to 0.04g – the site of Saclay is a low sismicity area
- implemented in the existing protection system (2/3 protection)

- new sensors



STRESS TESTS
SEISMIC RELATED SAFETY IMPROVEMENTS

Protection againts seismic induced flooding

- water proof door to the access of the machinery of the material lock to the reactor building : ensure the operability of the equipment in extreme situation (after extreme seism)

- Implementation of an automatic cofferdam

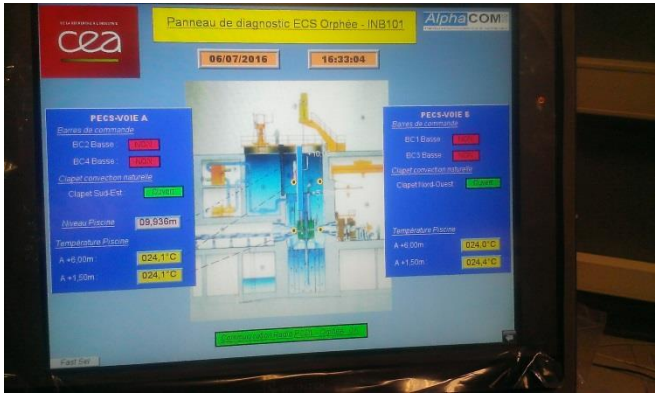
  to prevent flooding the ventilation systems

STRESS TESTS
SEISMIC RELATED SAFETY IMPROVEMENTS

Ultimate control panel (panneau ECS – ECS), part of the hard core

- objective: allow the monitoring of the safe of the reactor in extreme situation
- In extreme situation: unavailability of the main control room and of the backup control panel
- Available information:
  - « Low position » of the control rods (all inserted)
  - « Open position » of the natural convection check valves
  - Water level and temperature in the reactor pool
  - Electrical backup for the opening of the material lock
- set up in a building verified to extreme seism
- automatic transmission of the information

  to the PCD-L (crisis management room)



STRESS TESTS
SEISMIC RELATED SAFETY IMPROVEMENTS

Ultimate control panel (panneau ECS – ECS), part of the hard core

- designed and tested for extreme seism situations: qualification of the electrical device on TAMARIS

- Power feeding
  - Ultimate diesel generator (GECS)
  - independant and adapted to extreme seism situations

STRESS TESTS
SEISMIC RELATED SAFETY IMPROVEMENTS

Water injection by mobile pumping systems

- allow a water fillling of the reactor pool in case of unavailability of the existing means (normal and emergency from the backup panel)
- implementation of an additional plug for firemen piping
- training: periodic test of the equipment with

  the fire protection teams of the site of Saclay

CONCLUSION

Continued safety review and improvement process (regulatory basis or operating experience) have led to the improvement of procedures and operating conditions and implementation of new equipment

In the field of external hazards, the site of Saclay has a low sismicity. Important works and utility modifications have ben implemented to reinforce its robustness and fulfill the evolution of requirements for seismic hazard.

For the next periodic safety review, the safety reassessment will be covering the specific activities related to the definitive shutdown state and in the longer term, decommissioning,