IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Faire avancer la sûreté nucléaire

Approach implemented by IRSN for the assessment of periodic safety reviews on French research reactors

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INTRODUCTION

- French regulatory (law on transparency and nuclear security):
  ⇨PSR is required to operator every 10 years

- This operator's review is composed of:
  - A conformity check of the facility (with regard to safety reference files and preceding modifications)
  - A safety reassessment of risks related to the facility (with safety rules changes and technical scientific advancements)
  - The experience feedback of the installation and similar facilities in France and abroad

- In conclusion, the operator usually identifies a list of provisions to improve the safety of his facility

INTRODUCTION

- A final report with the conclusions of PSR is submitted to the **French Nuclear Safety Authority (ASN)**
- **As Technical Support Organization, IRSN critically examines this safety review and presents its conclusions and demands to a standing panel of experts (GPR) mandated by the ASN**
- **The ASN decides the continuation of reactor operation for ten years (towards the next PSR) and the improvements to be done on the facility (on basis of the GPR judgement)**

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IRSN TECHNICAL ASSESSMENT

IRSN assessment approach

- IRSN assesses how the operator took into account for the safety review:
  - Environment changes (increase of air/road traffic, additional facilities…),
  - Regulatory changes,
  - Safety rules/approaches changes,
  - Knowledge and technical advancements,
  - …and the state/lack of the safety demonstration before the PSR.
- The assessment is applied to the following aspects:
  - External and internal hazards,
  - Radiological protection of workers,
  - Reactor operation safety,
  - Fuel storage safety,
  - Handling operation safety,
  - Confinement towards the environment,
  - Radiological consequences of accidents considered in the safety assessment.
- For all topics human activities are taken into account

IRSN TECHNICAL ASSESSMENT

IRSN assessment approach

- Some examples:
  - New decrees which modify the rules used for fire risk analysis and impose a new safety demonstration (building resistance under fire)
  - Evolution of safety rules for the definition of the seismic hazards
  - New regulations for radiological protection of workers
  - New approach for the safety analysis: **Operating conditions analysis**
- In addition to elements available in the operator report, IRSN assessment relies on:
  - Findings of the ASN safety inspections
  - Operation annual reports established by the operator (annual activities, maintenance findings, nature and quantity of gas and liquid released, worker's annual dose…)
  - Incident declarations

IRSN TECHNICAL ASSESSMENT

IRSN organization

IRSN
- Pilot (*generalist engineer*)
- Experts

→ **Assessment** (*≈ 18 months*) → **Recommendations** (*GPR*)

OPERATOR

Completed with a **technical dialogue** with operator (discussions on submitted elements and additional useful information):

- Formal questionnaires
- Technical meetings
- Visits of the installation and human activities observations

Improvements and consolidation of operator safety demonstration (in case of weaknesses) by **IRSN propositions**:

- Operating rules
- Additional studies
- Physical modifications and refurbishments

From assessment to enhancing safety level

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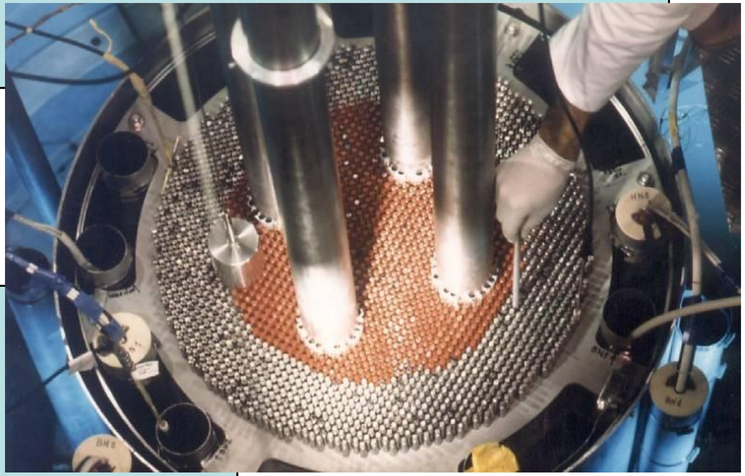
REACTOR OPERATION ASSESSMENT

➚ Two types of risks considered

Cooling accidents
- Loss of flow (pump dysfunctions, fuel channel blockage…)
- Loss of coolant (failure of primary circuit, damaged pool…)
- Loss of heat sink



Reactivity accidents
- Moderator changes
- Control rod lift
- Fuel loading errors
- Failure of experimental devices

REACTOR OPERATION ASSESSMENT

Operating condition approach

- Context : **operating conditions analysis** not performed at the design stage for operating reactors

- This kind of analysis consists in :
  - Identifying initiators of an accidental sequence
  - Classifying accidental sequences in categories depending on their occurrence probability,
  - Defining safety objectives for each category (radiological consequences and core state)
  - Verifying the compliance of accidental sequences consequences with safety objectives

This new analysis is applied by operators in recent PSR

REACTOR OPERATION ASSESSMENT

IRSN assessment relies on defence in depth principle

- **Prevention of the occurrence of postulated initiating event**
  - Robustness of the design with regards to external/internal hazards loadings (for example, consideration of seismic loadings)
  - In-service inspections / preventive maintenance
- **Detection of the occurrence of postulated initiating event**
  - Capability and reliability of safety systems (redundancy and diversity of monitoring systems) to detect events
  - Periodic tests
- **Safety actions to limit damages on the reactor core**
  - Capability and reliability of safety systems to lead to a safe state of the reactor (verification of safety thresholds notably by computer codes which must be "qualified" to research reactors specificities: low pressure, high cooling flow)
  - Periodic tests

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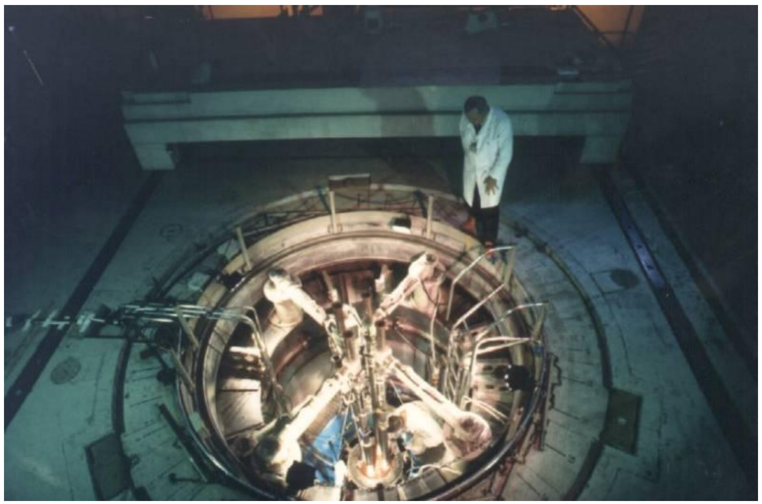
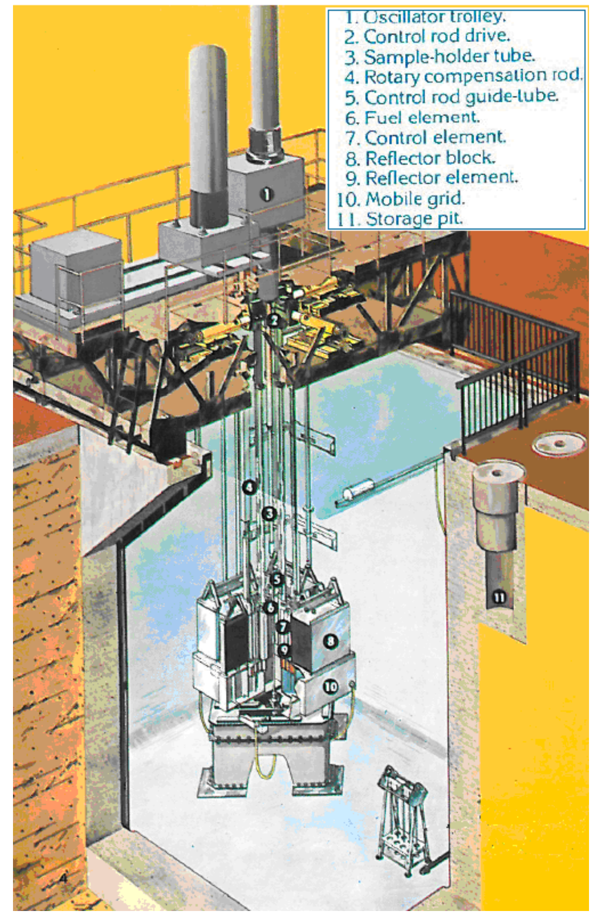
EOLE AND MINERVE REACTORS

EOLE AND MINERVE REACTORS

➚ Two zero power reactors without core cooling system



EOLE reactor: critical mock-up (1 kW) for neutronic studies



MINERVE pool type reactor (100 W) to neutronic measurements

EOLE AND MINERVE REACTORS

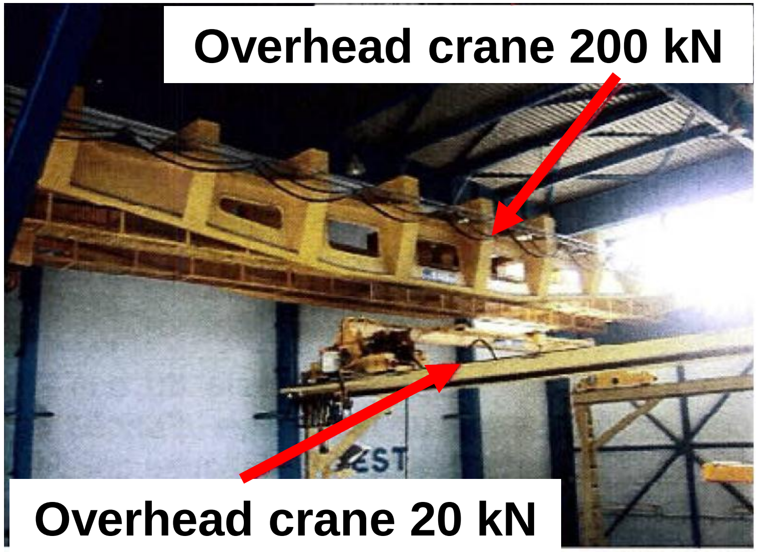
↗ IRSN assessment conclusion: reactors operation are safe

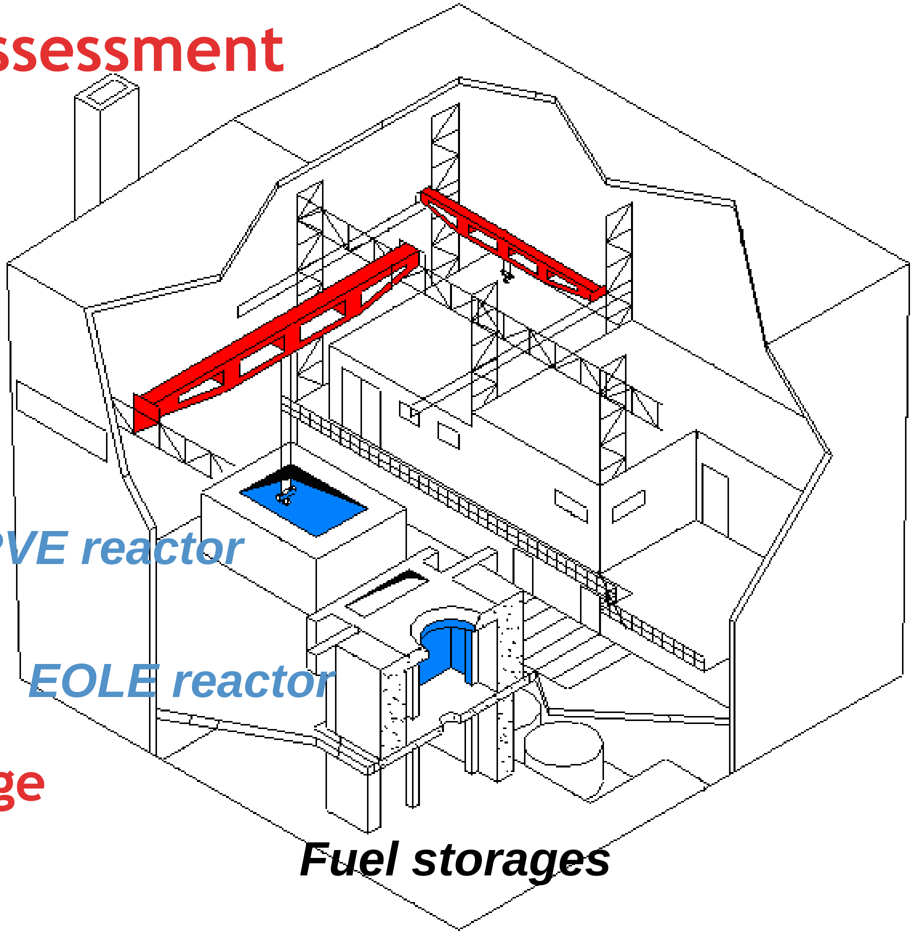
- A low reactivity potential imposed by operation rules (notably with a maximum super-criticality like ß/2 for EOLE reactor)
- Different checks performed by workers before initiating a sub-critical approach (core configuration, control rod type…)
- At least, the sub-critical approach allows to detect (in case of a failure of previous dispositions) an abnormal core reactivity
- Calculations of reactivity accidents consequences pointed out that there is no impact on the core of each reactor even with an emergency scram failure

↗ Main safety issues are not linked to the operation

EOLE AND MINERVE REACTORS

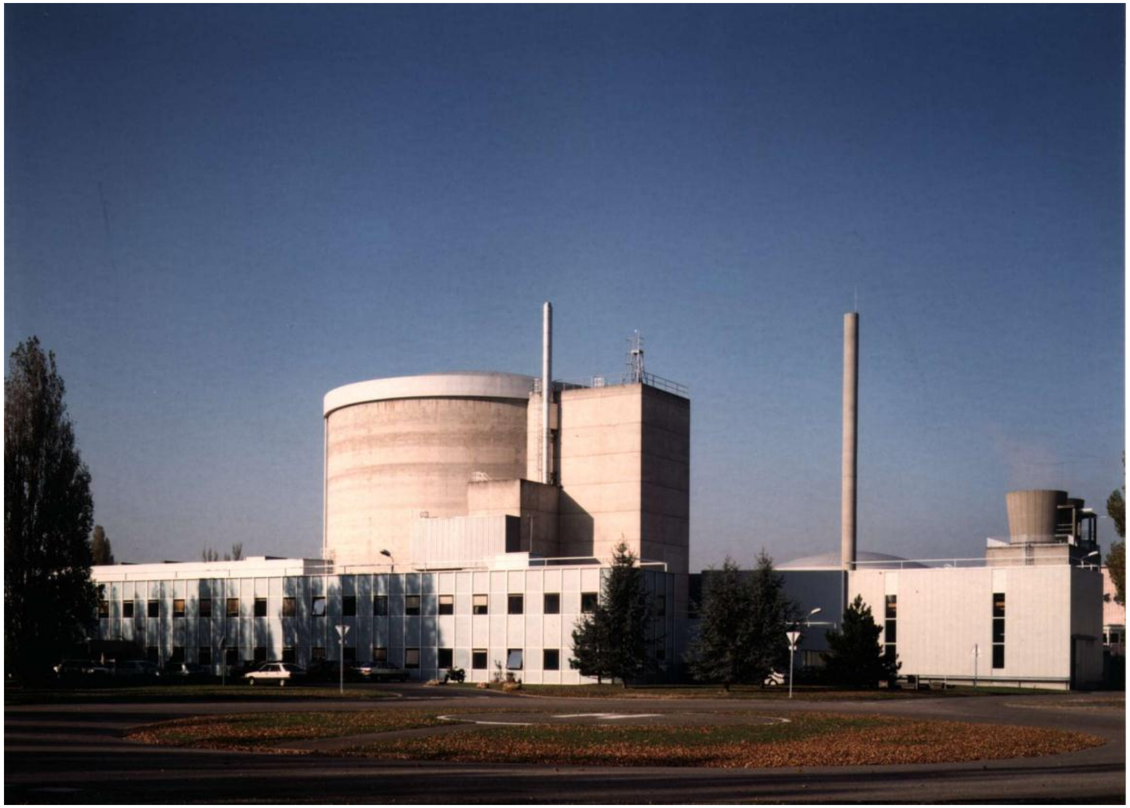
- Conclusions of IRSN safety assessment



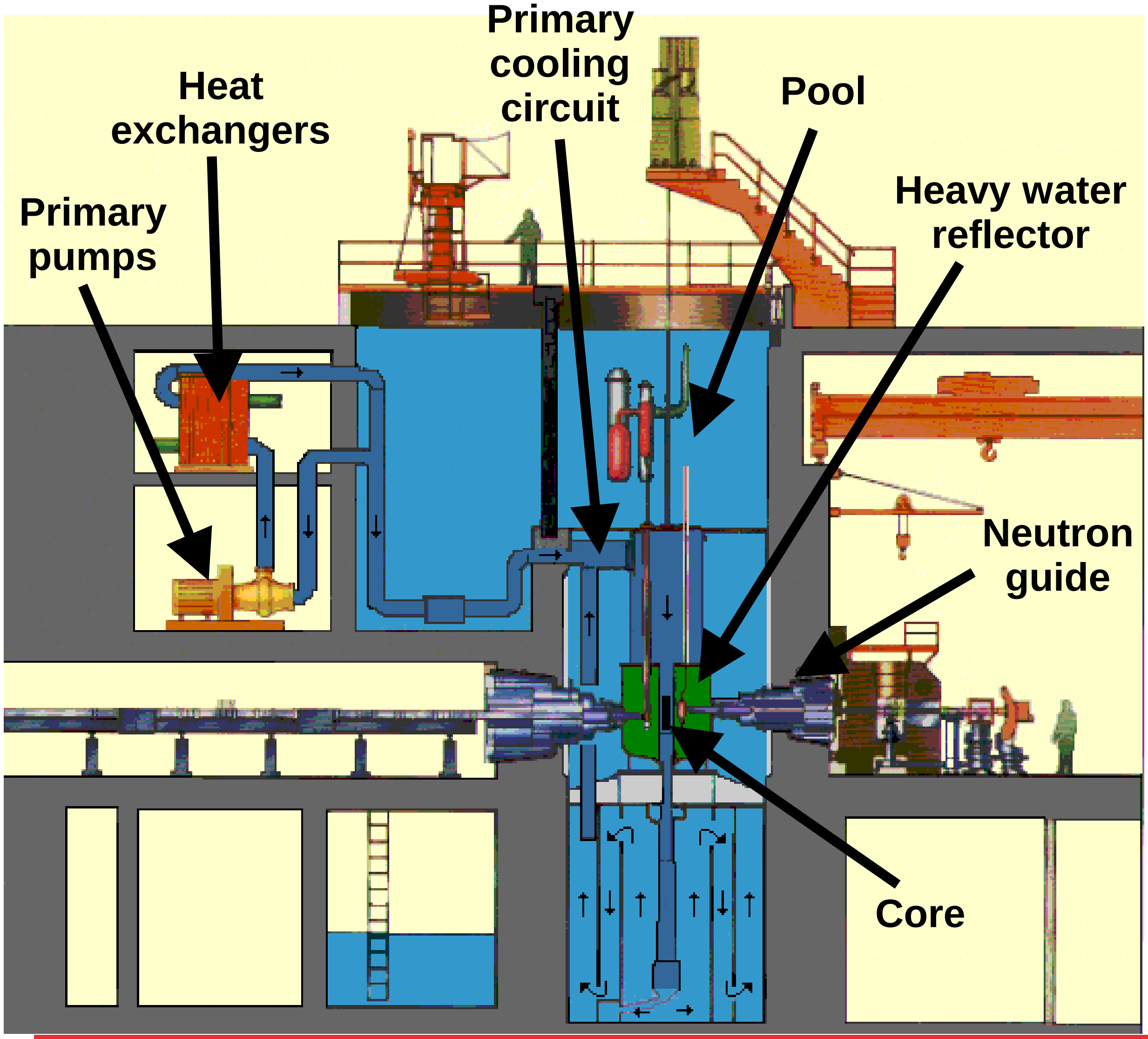


- Main safety issues result from large movements of fissile materials
  - Handling operation
  - Criticality control

ORPHEE REACTOR



ORPHEE REACTOR



- 14 MW pool-type reactor operated by the CEA
- Located 20 km from Paris
- Purpose
  - To supply neutron beams for fundamental research
  - To produce artificial radionuclides for pharmaceutical industry

ORPHEE REACTOR

➚ Operation safety assessment: Cooling accidents

- Redundancy of emergency scram in case of flow loss (abnormal pressure or temperature in the core)
- Flywheels on the pumps of the primary cooling circuit ensure a sufficient flow in the core for a short time
- Then, natural convection (passive system) is sufficient to evacuate residual power (weak residual power),
- Due to the conception of the primary cooling circuit (contained in leaktight bunkers: waterblock) core uncovering is impossible.

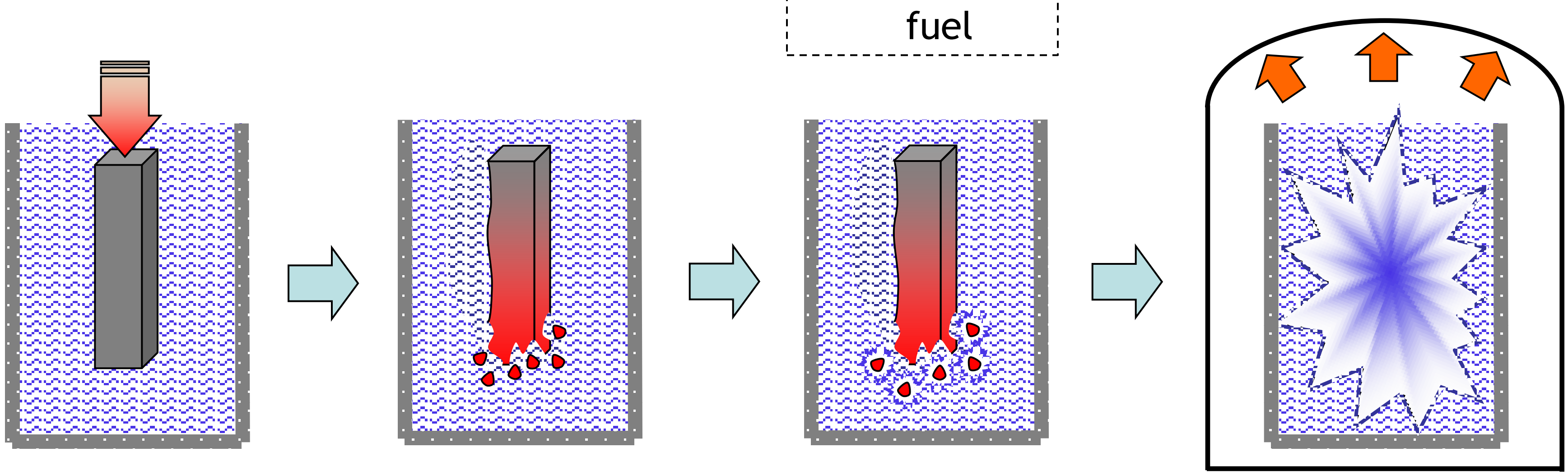
➚ IRSN conclusion:

Core cooling is ensured for most of accidental sequences

ORPHEE REACTOR

➚ Operation safety assessment: Reactivity accidents Focus on the BORAX type accident (Design basis accident)

Quick and significant reactivity insertion → Melting of the aluminium of the core → Interaction between coolant and the molten fuel → Steam explosion



The pressure wave impacts the structures of the pool

ORPHEE REACTOR

Operation safety assessment: Reactivity accidents

- Safety requirement: avoid core uncovering in case of explosive BORAX type accident

- Assessment of the pool pressure loading in case of BORAX type accident
  - Calculations performed by IRSN with up-to-date calculation tools (modeling the fuel-water interaction)

  ⇨question the conservatism of the design loading

Importance of prevention of a BORAX type accident

Importance of ultimate means available to keep the core under water

ORPHEE REACTOR

Operation safety assessment: Reactivity accidents Assessment of prevention robustness

- Identification of initiators of a BORAX type accident
  - Neutronic calculations performed by IRSN to evaluate reactivity insertions

  ⇨simultaneous destruction of experimental devices can lead to a BORAX type accident

- Assessment of initiators prevention

  ⇨**The operator has to revise the replacement planning of experimental devices to avoid their failure at the same time**

ORPHEE REACTOR

➚ Conclusions on reactor operation safety

- **Cooling accidents: appropriate prevention, detection and safety actions to limit consequences**

- **Reactivity accidents:**
  - Prevention of reactivity accidents has to be improved
  - It is interesting to have a well designed booster water circuit to avoid core uncovering in case of pool degradation after a BORAX accident

SUMMARY / CONCLUSION

- ✓IRSN assessment
  - ✓All risks are reviewed
  - ✓Safety issues depend on reactors specific features
  - ✓Specific organization (important means and resources)
  - ✓Strong interactions with operator

- ➚ Keep improving reactor safety level even after PSR
  - ➚On-site inspections
  - ➚Evaluation of operator answers to ASN recommendations (PSR assessment)

Thanks for your attention