IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

*Faire avancer la sûreté nucléaire*

# Safety approach of BORAX Type accidents in French Research Reactors

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Système de management
de la qualité IRSN certifié

# Contents of the presentation

- Context: Safety of French Research Reactors
  - Reactivity Insertion Accidental Transients: Borax
- Analysis of the initiating events: reactivity insertions
- Evaluation of the consequences on the core
- Conclusions and perspectives

# Context

## Safety of Research Reactors in France

# Role of IRSN in nuclear safety

- IRSN is the Technical Support Organisation of the French Nuclear Safety Authority.
- At all stages of the facility's life, IRSN verifies that the safety demonstrations are solid, and comply with the safety regulations
- Recent activities in Research Reactors
  - Preliminary safety review of JHR
  - Decennial safety review of ORPHEE, EOLE and MINERVE
  - Complementary global safety review to include the Fukushima feedback
  - Publication of a Reference document about BORAX in RR Safety

# What are the safety requirements ?

- Containment of radioactive material
  - The fuel must always remain covered in water in any situation,  more importantly after a core-damaging accident.

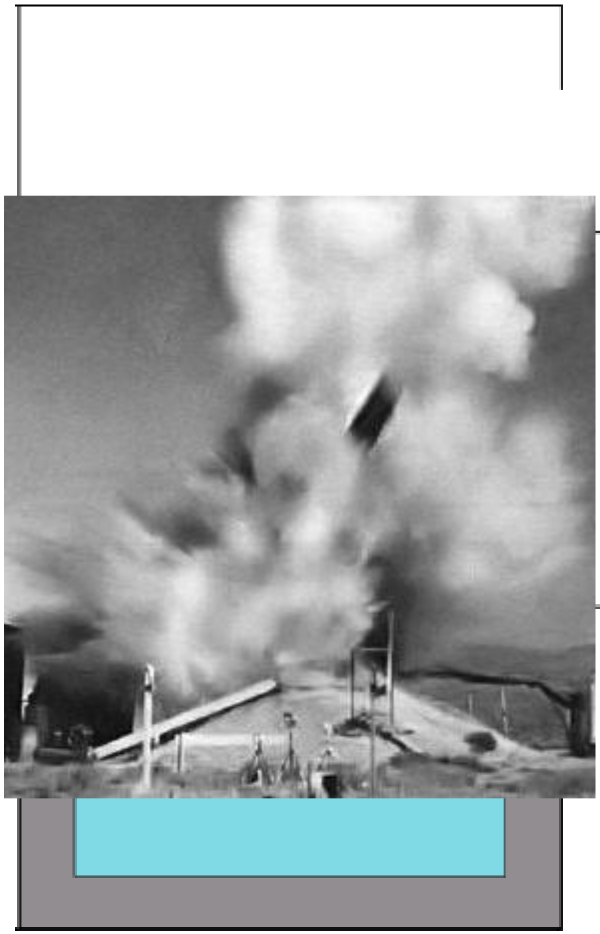
- Practically: The pool walls must be designed to prevent water leakage
  - This requirement must be met with robust defense lines (defense in depth)

➔BORAX transients are the reference loading to design the containment of research reactors
  - Beyond Design Basis Accident

# What is a Borax accident?

- Explosive fast transient observed in research reactors
  - Experimentally: BORAX, SPERT-I
  - **Accidentally: SL-1**
- Particularities of Research Reactors?
  - High reactivity insertion potential (heavy rods)
  - Use of aluminum as fuel plate structure material (meat and cladding)
  - ➔Low melting point (660°C)
- Non destructive tests were also carried out
  - SPERT-IV

# What happens during the accident?



Uncovering of the core

>Radioactive material release

Breach in containment

>Radioactive material release

**Important data**

Reactivity

↓

Power

↓

Energy / Temperature

↓

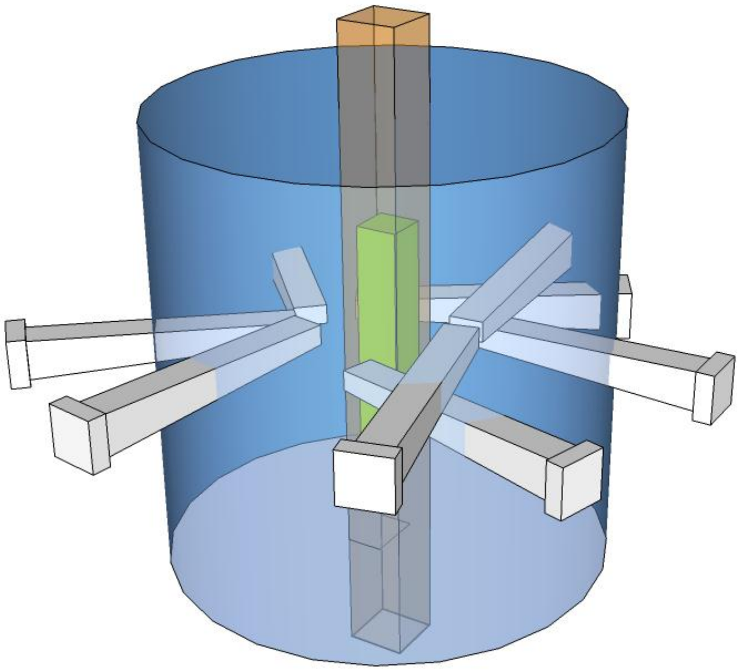
Pressure

↓

Activity

# Step 1:
# Initiating events: reactivity insertions

## Qualitative and quantitative investigation



# Envelope scenario analysis

- Various reactivity insertions initiators:
  - Rod ejection (JHR)
  - Reflector effect (ORPHEE)

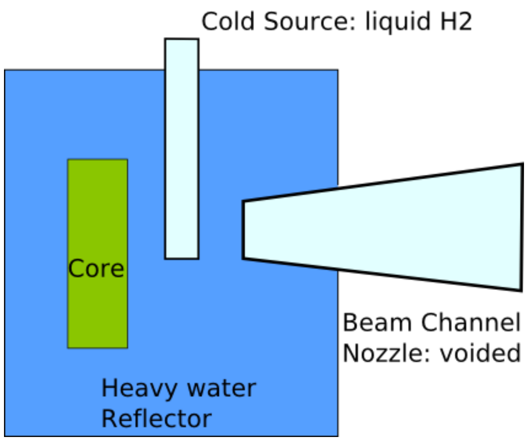
➔ Conservative scenario

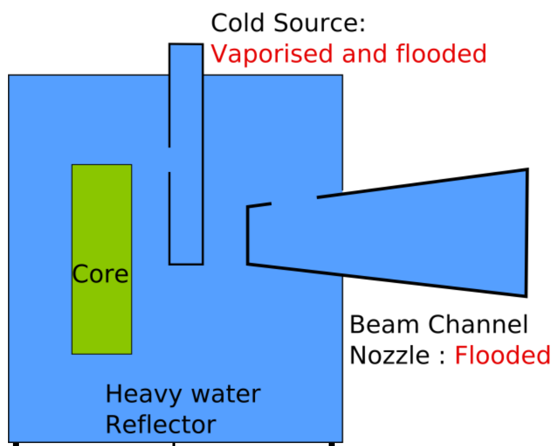
- Static neutronic calculations are carried out
  - Use of Monte Carlo models to adapt to the large spectrum of designs

  ➔Home-made MC criticality code: MORET5 (several developments in progress)
  - Models are always validated against experimental data or other reference codes

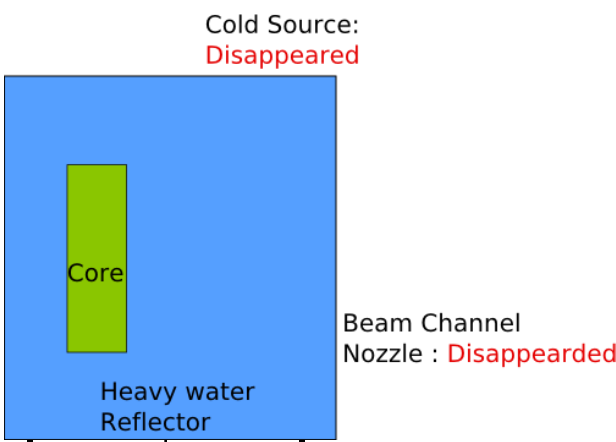
# Envelope scenario quantification

## ORPHEE: flooding / disappearance of structures




| 1970 | 2010 |
|---|---|
| 1.46 $ | 2.66 $ |

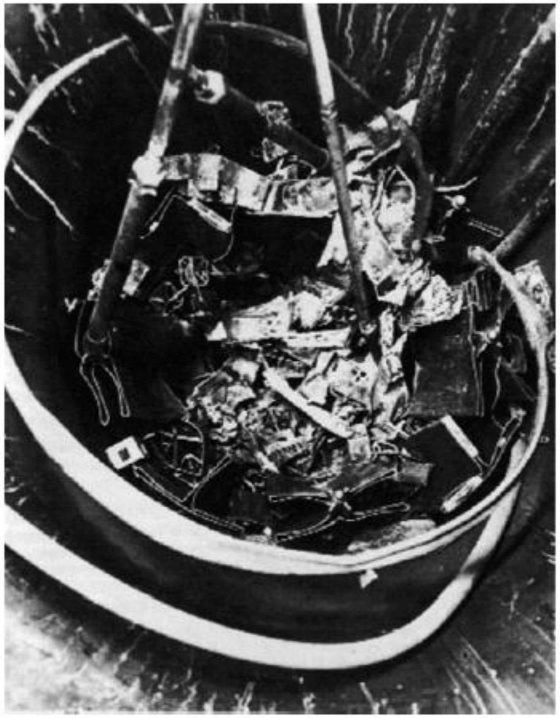



| 1970 | 2010 |
|---|---|
| 2.9 $ | 4.3 $ |

- Calculated values were underestimated during design phase
- Preventive actions are planned

# Step 2
# Analysis of the consequences on the core

## Transient calculations



# Energy source term for the steam explosion

- The pressure load on the containment walls is determined by the energy available at the time of the Fuel/Coolant Interaction

➔ Source term estimation

- Lack of knowledge about several physical phenomena
  - ➔ Large uncertainties on the results

**➚ IRSN assessment is based on simple conservative calculations and relevant experimental feedback**

# Power transient calculation

## ➚ Simplified calculation tool: 0D modelisation

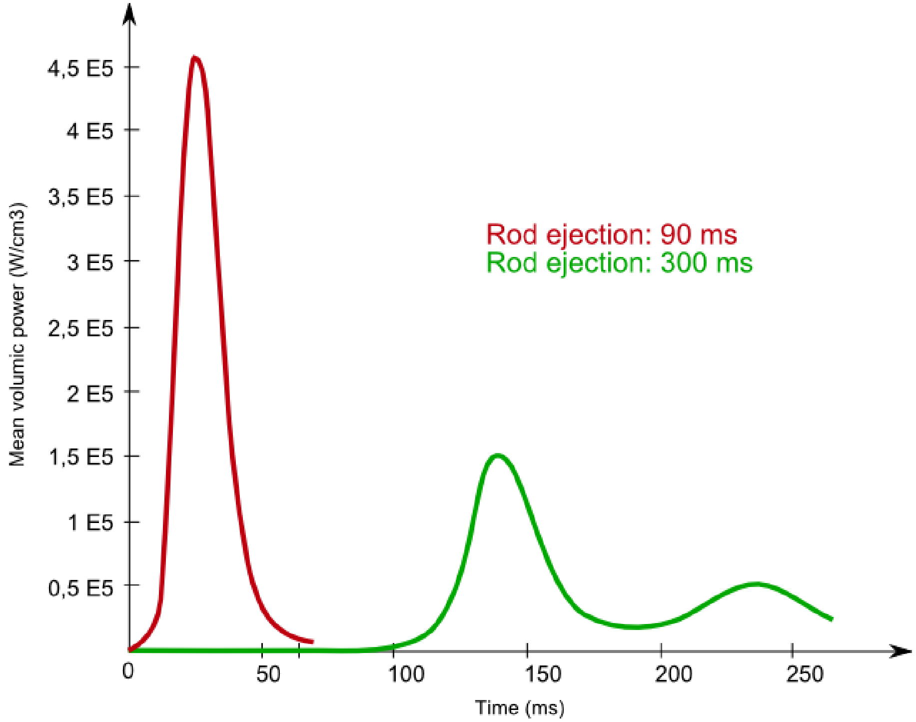
- Point kinetics ➔ Mean power evolution
- Heat generation in the fuel ➔ Fuel Temperature increase
  ➔ Doppler feedback effect
- Clad/Coolant heat exchange ➔ Water density decrease
  ➔ Moderator feedback effect
  - Too many unknowns on the transient boiling phenomena
  - Available Heat Transfer coefficients are not compatible with JHR conditions

  ➔ No heat exchange used: no moderator feedback ➔ conservative results

# Power transient calculation

## Simulation of the JHR scenario

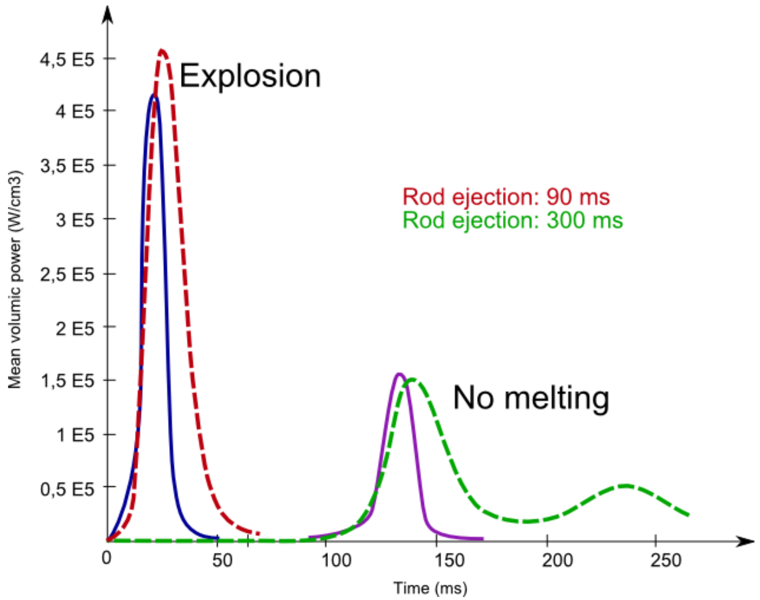
- Two ejection speed hypotheses
  - Design / Conservative value: 90 ms
  - Realistic value: 300 ms



# Power transient calculation

## ➚ Comparison with relevant experimental feedback

- SPERT: instrumented transient runs
  - SPERT-I-54 : ultimate destructive test
  - SPERT-IV-B16: most violent self limiting transient ➔ no melting




## ➚ Similarities in core behaviours

# Conclusions

- The containment's most challenging accident is analyzed on every level

- If required, IRSN is able to deploy technical studies to support the safety expertise. They offer the opportunity

➔ To investigate and comprehend the underlying physical phenomena

➔ To highlight fragile areas and target the need for R&D

  - Heat exchanges in fast transient

➔ To engage in rich technical discussions with the utilities

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## Thank you for your attention!

http://www.irsn.fr/FR/Larecherche/publications-documentation/collection-ouvrages-IRSN/Documents/BORAX_texte_VA_290811.pdf