SAFETY ASSESSMENT AND VERIFICATION IN THE REGULATORY BODY AND THE OPERATING ORGANISATION (French Research Reactor Case)

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GENERAL PRESENTATION OF THE INSTALLATIONS

- **11 RESEARCH REACTORS IN OPERATION AND 6 REACTORS SHUT DOWN (*MELUSINE, SILOE, SILOETTE, SCARABEE, HARMONIE, R.U.S*)**

- **OPERATING RESEARCH REACTORS WERE BUILT BETWEEN 1961 *(ULYSSE*, 100 kW) AND 1980 (*ORPHEE*, 14 MW) .**

- **2 OPERATING ORGANIZATIONS : C.E.A AND I.L.L. (R.H.F)**

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GENERAL PRESENTATION OF THE INSTALLATIONS

- 1 MULTIPURPOSE REACTOR : *OSIRIS* (70MW)

- 2 REACTORS USED MAINLY FOR BASIC RESEARCH :
  ORPHEE (14 MW) AND *R.H.F* (58,3 MW)

- 2 REACTORS DEDICATED TO SAFETY STUDIES :
  CABRI (25 MW) AND *PHEBUS* (38 MW)

- 1 REACTOR FOR TRAINING : *ULYSSE* (100 kW)

- 4 SPECIAL REACTORS : *MASURCA* (5 kW), *EOLE* (10 kW), *MINERVE* (100 W) AND *ISIS* (700 kW)

- 1 PULSED REACTOR : *NEUTRONGRAPHY REACTOR OF PHENIX*

TYPE OF OPERATING RESEARCH REACTORS

- 8 POOL-TYPE REACTORS
- 1 FAST NEUTRON REACTOR (MASURCA)
- 1 ARGONAUT REACTOR (ULYSSE)
- 1 AQUEOUS HOMOGENEOUS SOLUTION REACTOR
- (NEUTRONGRAPHY REACTOR OF PHENIX)

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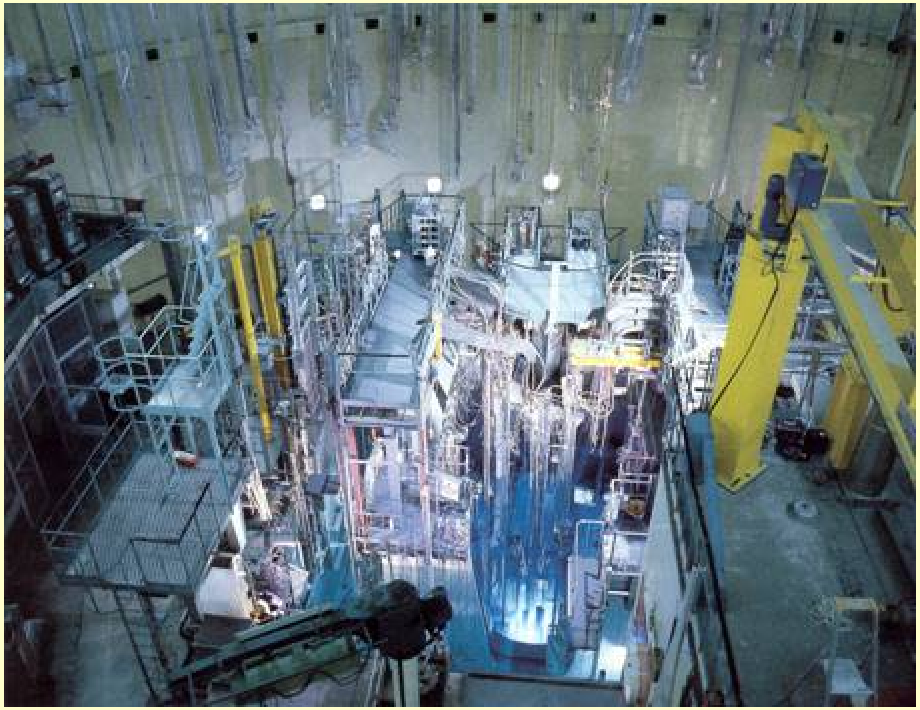
EXPERIMENTAL DEVICES

- **Capsules and tubes for various material irradiation**
- **Pressurised and high temperature loops**
  - Pressurised water loops
  - Sodium loops
  - Pressurised gas loops
- **Neutron beam tubes**
- **Cold and hot neutron sources**



CREATION OF THE CURRENT SAFETY AUTHORITY AND ITS TECHNICAL SUPPORT

- 2002 (decree n° 2002-254 published on 22 February 2002) : Creation of the IRSN (Institut de Radioprotection et de Sûreté Nucléaire).

- 2002 (decree n° 2002-255 published on 22 February 2002) : Creation of the DGSNR (Direction Générale de la Sûreté Nucléaire et de la Radioprotection).

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ROLE OF THE SAFETY AUTHORITY AND THE OPERATING ORGANISATIONS

- THE SAFETY AUTHORITY DEFINES THE GENERAL SAFETY AND RADIATION PROTECTION OBJECTIVES.

- THE OPERATING ORGANISATIONS PROPOSE THE TECHNICAL PROVISIONS TO MEET THESE OBJECTIVES.

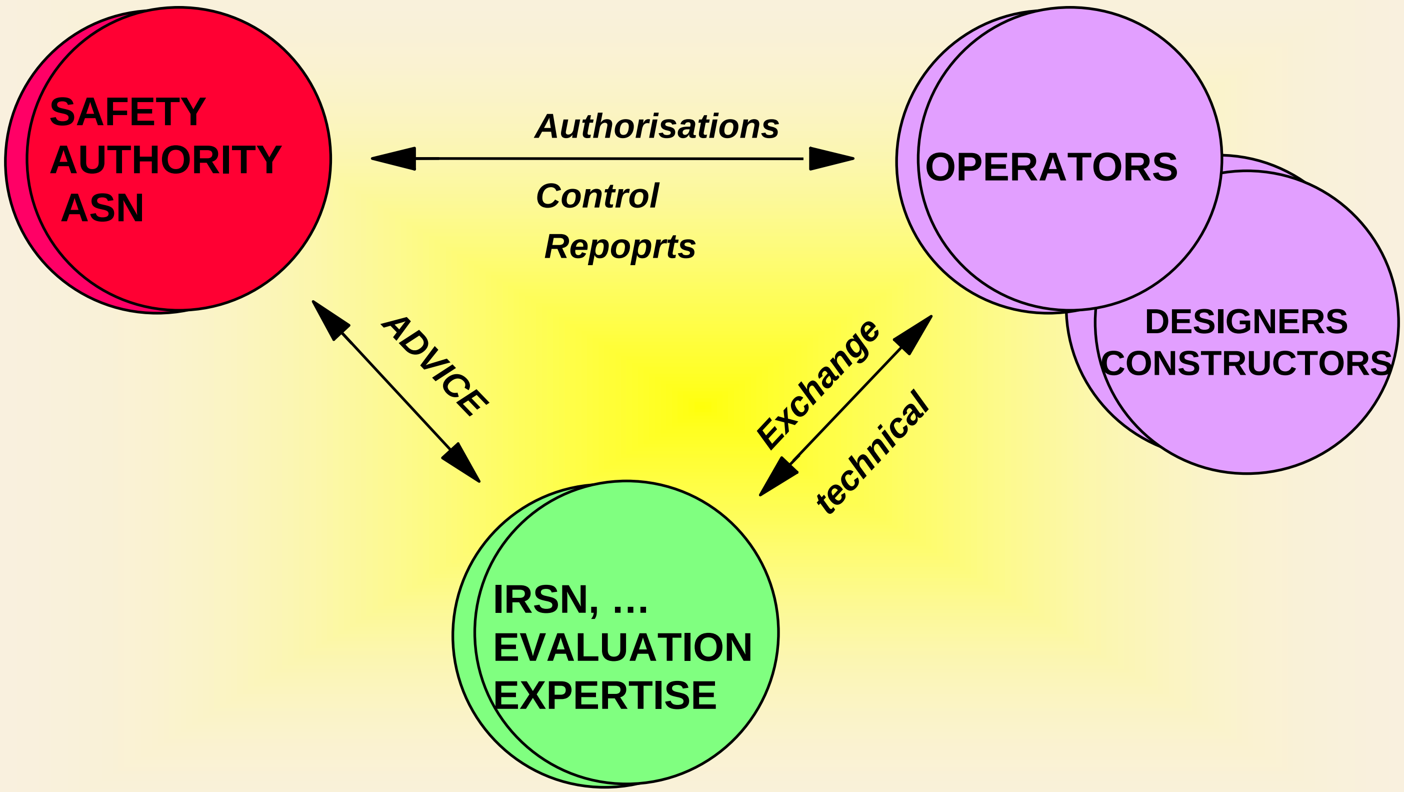
- THE SAFETY AUTHORITY ASSESS THE VALIDITY OF THE PROPOSED PROVISIONS.

ROLE OF THE SAFETY AUTHORITY AND THE OPERATING ORGANISATIONS

- AFTER APPROVAL BY THE SAFETY AUTHORITY, THE OPERATING ORGANISATION IMPLEMENT THE APPROVED TECHNICAL PROVISIONS.

- THE SAFETY AUTHIRITY VERIFY THEIR EFFECTIVE IMPLEMENTATION.

NUCLEAR SAFETY ORGANISATION



SAFETY ANALYSIS METHODOLOGY

- DETERMINISTIC APPROACH IS APPLIED : SOME INCIDENTS AND ACCIDENTS ARE ASSUMED.
- BARRIERS ANALYSIS METHOD IS USED FOR THE DIFFERENT RESEARCH REACTORS.
- THE ANALYSIS COVERS THE PROVISIONS RELATING TO PREVENTION, SURVEILLANCE AND SECURITY ACTIONS ASSOCIATED WITH EACH SAFETY BARRIER.

MAIN SAFETY REQUIREMENTS (1)

GENERAL ASPECTS:

- SAFETY REQUIREMENTS FOR RESEARCH REACTOR HAVE CHANGED OVER TIME.
- REQUIREMENTS RELATING TO INTERNAL AND EXTERNAL HAZARDS, TO REDUNDANCY AND SEPARATION OF PROTECTION SYSTEM CHANNELS, TO CONTAINMENT BUILDING LEAKTIGHTNESS HAVE BEEN GRADUALLY ESTABLISHED AND APPLIED.

MAIN SAFETY REQUIREMENTS (2)

- SOME RULES ESTABLISHED FOR THE DESIGN OF NUCLEAR POWER PLANTS ARE APPLIED TO RESEARCH REACTORS WITH ADAPTATIONS (GRADED APPROACH) DUE TO SPECIFIC FEATURES OF CERTAIN REACTORS (SHORT OPERATING TIME, LOW RADIOACTIVE PRODUCT INVENTORY).

MAIN SAFETY REQUIREMENTS (3)

SPECIFIC ASPECTS:

- **REACTOR OPERATION IS NOT ALLOWED WITH FAILED FUEL.**

- **MECHANICAL RESISTANCE AND TIGHTNESS OF THE POOL AND REACTOR CONTAINMENT BUILDING SHALL BE ENSURED IN NORMAL OPERATION AND ACCIDENT CONDITIONS (EARTHQUAKES, FIRES, INTERNAL OR EXTERNAL FLOODS, INTERNAL OR EXTERNAL EXPLOSIONS, AIR CRAFT CRASHES).**

MAIN SAFETY REQUIREMENTS (4)

- IN THE CASE OF A PIPE BREAK OR A WINDOW FAILURE IN NEUTRON BEAM TUBES, THE CORE MUST REMAIN FLOODED BY PASSIVE MEANS (POOL BLOCK DESIGN).

- REQUIREMENTS FOR NEUTRONIC AND THERMAL-HYDRAULIC CORE DESIGN
- CONSIDERATION OF A BORAX TYPE REACTIVITY ACCIDENT APPLIED AT THE OUTSET TO ALL FRENCH POOL TYPE RESEARCH REACTORS.

MAIN SAFETY REQUIREMENTS (5)

- THERMAL-HYDRAULIC SAFETY CRITERIA :
  - NO NUCLEATE BOILING UNDER NOMINAL POWER AND COOLANT FLOW CONDITIONS.
  - NO FLOW REDISTRIBUTION NOR CRITICAL HEAT FLUX IN OPERATION AT THE LIMITS OF THE MAXIMUM POWER AND MINIMUM COOLANT FLOW SAFETY THRESHOLDS.
  - IN THE CALCULATIONS : WORST CASE UNCERTAINTIES ARE CUMULATED AT THE HOT POINT OF THE FUEL.

REFERENCE ACCIDENT FOR POOL-TYPE REACTORS

- BORAX TYPE REACTIVITY ACCIDENT (EXPLOSIVE ACCIDENT) IS ASSUMED AS THE REFERENCE ACCIDENT FOR POOL-TYPE RESEARCH REACTORS USING URANIUM-ALUMINIUM FUEL.

- TOTAL CORE MELTING IS ASSUMED DURING THE ACCIDENT.

- THE SAFETY REQUIREMENTS ARE TO KEEP THE CORE FUEL FLOODED AND NOT TO DAMAGE THE CONTAINMENT

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BORAX TYPE ACCIDENT (1)

- HYPOTHESIS ADOPTED FOR FRENCH POOL-TYPE RESEARCH REACTORS:

  - PERCENTAGE OF MOLTEN ALUMINIUM: 100 %

  - MEAN TEMPERATURE: 800°C

  - DURATION OF THERMAL ENERGY TRANSMISSION BETWEEN FUEL PLATES AND POOL WATER: 30 ms

BORAX TYPE ACCIDENT (2)

- TOTAL THERMAL ENERGY: 135 MJ

  (THE THERMAL ENERGY DUE TO THE DESTRUCTION OF HOT SOURCES SHOULD BE ADDED)

- CONVERSION RATE OF THERMAL ENERGY INTO MECHANICAL ENERGY: 9 %

BORAX TYPE ACCIDENT STUDIES

- **EXPERIMENTAL STUDIES USING EXPLOSIVE MATERIALS IN REDUCED SCALE MOCK-UPS OF THE DIFFERENT REACTORS (SIMULATION OF THE ENERGY RELEASED DURING THE ACCIDENT)**

- **VERIFICATION OF THE NEUTRON BEAM TUBE AND POOL LEAKTIGHTNESS CONSERVATION.**

- **USE OF CALCULATION CODES TO CHECK THE MECHANICAL RESISTANCE OF THE REACTOR POOL AND TO DETERMINE THE OVERPRESSURE IN THE CONTAINMENT.**

CALCULATION OF THE RADIOLOGICAL CONSEQUENCES

INSTANTANEOUS F.P. RELEASE RATE	MOLTEN FUEL → POOL WATER	POOL WATER → CONTAINMENT AIR
NOBLE GASES	100%	5%
IODINE AND CESIUM	80%	0,05 %
Sr, Ba, Ru, Rh	10%	
ACTINIDES	1%	
DIFFERED FP RELEASE RATE		POOL WATER→ CONTAINMENT AIR
NOBLE GASES		50 % per day
IODINE		0,0125 % per day

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CALCULATION OF RADIOLOGICAL CONSEQUENCES

- **CASE OF ORPHEE REACTOR :**

DOSES at 1 km (exposure time : 24 hours) :

0,19 mSv (thyroïd)

0,14 mSv (whole body)

AGEING AND SAFETY REASSESSMENT

- NO TIME LIMIT FOR RESEARCH REACTORS OPERATING LICENCE.
- SYSTEMATIC SAFETY REVIEW FOR RESEARCH REACTORS OPERATING FOR MORE THAN TEN YEARS.
- A PERIODIC SAFETY REVIEW SCHEDULE WAS ESTABLISHED FOR OPERATING RRS AND THEIR EXPERIMENTAL DEVICES UNTIL 2010 (THE MOST POWERFUL REACTORS WERE ALREADY REASSESSED).

AGEING AND SAFETY REASSESSMENT

- **REVIEW OF THE OPERATING CONDITIONS AND THE DEFENCE-IN-DEPTH ASPECTS (IDENTIFICATION AND CORRECTION OF POSSIBLE DISCREPANCIES WITH NEW SAFETY REQUIREMENTS).**

TOPICS EXAMINED AT EACH SAFETY REASSESSMENT

- **UPDATED SAFETY DOCUMENTS OF THE FACILITY.**
- **OPERATIONAL EXPERIENCE FEEDBACK AND LESSONS LEARNED FROM INCIDENTS.**
- **DATA AND INFORMATION CONCERNING THE OPERATIONAL STAFF (MOBILITY, TRAINING, DOSES…).**
- **RADIOACTIVE EFFLUENT RELEASES AND MANAGEMENT OF SOLID RADIOACTIVE WASTES.**

CONCLUSION

- **SAFETY ORGANISATION IN FRANCE IS CONFORM TO THE PROVISIONS OF THE CODE OF CONDUCT ON THE SAFETY OF RESEARCH REACTORS.**
- **SAFETY REQUIREMENTS CURRENTLY APPLIED TO RESEARCH REACTORS IN FRANCE ARE CONSISTENT WITH THE RECOMMENDATIONS ISSUED BY THE IAEA.**
- **CURRENT SAFETY REQUIREMENTS WITH SOME EVOLUTIONS OF THE SAFETY ANALYSIS METHODOLOGY WILL BE TAKEN INTO ACCOUNT FOR THE DESIGN OF THE NEW RESEARCH REACTOR RJH.**