RA-10: a New Argentinian Multipurpose Research Reactor

H. Blaumann, A. Vertullo, F. Sánchez, F. Brollo, J. Longhino

Nuclear Engineering Department
National Atomic Energy Commission
Argentina

International Conference on Research Reactors
Rabat, Morocco, November 14-18, 2011
## Present nuclear facilities: RR + NPP

<table>
<thead>
<tr>
<th>Reactor</th>
<th>Type</th>
<th>Location</th>
<th>Main Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA-0</td>
<td>RA-1 critical facility</td>
<td>Córdoba University</td>
<td>Human resources for nuclear industry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Promote nuclear energy applications</td>
</tr>
<tr>
<td>RA-4</td>
<td>Siemens SUR 100 critical facility</td>
<td>Rosario University</td>
<td></td>
</tr>
<tr>
<td>RA-1</td>
<td>UO2-graphite fuel rods, water cooled and moderated, tank reactor, 40 kW</td>
<td>Buenos Aires/CNEA</td>
<td>Long term material irradiations, nuclear instrumentation testing, training</td>
</tr>
<tr>
<td>RA-6</td>
<td>MTR, pool type, 1 MW</td>
<td>Bariloche/CNEA</td>
<td>Teaching/BNCT/NAA</td>
</tr>
<tr>
<td>RA-3</td>
<td>MTR, pool type, 10 MW</td>
<td>Buenos Aires/CNEA</td>
<td>RI production</td>
</tr>
<tr>
<td>Atucha I</td>
<td>PHWR</td>
<td>Lima/NASA</td>
<td>357 Mwe</td>
</tr>
<tr>
<td>CNE</td>
<td>CANDU</td>
<td>Embalse/NASA</td>
<td>648 Mwe</td>
</tr>
</tbody>
</table>
# Current nuclear projects

<table>
<thead>
<tr>
<th>NPP</th>
<th>TYPE</th>
<th>POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atucha II</td>
<td>PHWR</td>
<td>745 MWe</td>
</tr>
<tr>
<td>CNE+</td>
<td>life extension and power upgrade</td>
<td>656 MWe</td>
</tr>
<tr>
<td>CAREM 25</td>
<td>prototype for an Argentinean PWR reactor</td>
<td>25 MWe</td>
</tr>
<tr>
<td>RA-10</td>
<td>multipurpose RR</td>
<td>30 MW</td>
</tr>
</tbody>
</table>
# Argentinian Research Reactors

<table>
<thead>
<tr>
<th>REACTOR</th>
<th>POWER</th>
<th>LOCATION</th>
<th>CRITICALITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA-6</td>
<td>500 kW</td>
<td>Argentina</td>
<td>1982</td>
</tr>
<tr>
<td>RP-10</td>
<td>10 MW</td>
<td>Perú</td>
<td>1988</td>
</tr>
<tr>
<td>NUR</td>
<td>1 MW</td>
<td>Algeria</td>
<td>1989</td>
</tr>
<tr>
<td>ETRR-2</td>
<td>22 MW</td>
<td>Egipt</td>
<td>1997</td>
</tr>
<tr>
<td>OPAL</td>
<td>20 MW</td>
<td>Australia</td>
<td>2007</td>
</tr>
</tbody>
</table>
Why the RA-10 project?

• To provide a replacement for the RA-3 reactor (1967)
• To increase the RI production for supporting the local and regional future demand
  – 2500 Ci/w molybdenum-99
  – increase the production of lutecium-177 and iridium-192 and to try the generation of new RI such us bismut-213
  – with the Brazilian RMB might be relevant keys for LA self sufficiency in the supply of RI ensuring a natural back up
• To consolidate the national capabilities related to nuclear fuel production
  – to implement facilities for testing new fuel elements developments including miniplates, MTR and NPP fuel elements.
  – to implement facilities for materials testing focused on radiation damage and corrosion evaluation
Why the RA-10 project?

• To offer to the scientific and technological system new capabilities based on neutron techniques
  – to develop thermal and cold neutrons facilities for the applications of neutronic techniques to nuclear technology, material science and biology.
Steps in the project launching

• Potential stakeholders meetings (2009)

• Project inclusion in the CNEA 2010-2019 strategic plan

• Project approval by the government: «Design, construction and commissioning of an Argentinian multipurpose reactor: RA-10»

• Project officially started in CNEA (June 2010)
Reactor Site

• Ezeiza Atomic Center (Buenos Aires)

• Related facilities:
  • Spent fuel elements storage facility
  • Hot cells
  • Fission plant (molybdenum production)
  • Solid waste storage facility
  • Liquid effluent treatment plant
  • Ezeiza International Airport
Project advance

• **Conceptual design:**
  – Requirements specification related to reactor applications
  – Design criteria
  – SSCs classification
  – Reactor Systems
  – General Layout

• **Basic design:**
  – contract for the provision by INVAP (and CNEA)

• **Licensing:**
  – licensing basis (siting, design criteria, SSCs casification, initial events listing, safety features description)
• The Brazilian and Argentinian presidents signed a **Nuclear Cooperation Declaration** where they agreed to **intensify efforts** for implementing **the joint development** of a **multipurpose research reactor project** (August 3, 2010)

• The Argentinian and Brazilian National Nuclear Energy commissions, **CNEA** and **CNEN** formalized an **agreement** for a **joint development** of their **own projects**: the Brazilian RMB and the Argentinian RA-10 (January 31, 2011)
• A multipurpose facility suitable for RI production, material and fuel irradiation, neutron techniques and silicon doping.

• Based on LEU fuel elements

• Based on Argentinian Safety Regulations and IAEA Standards
  – Systematic approach to Safety Management (following IAEA NS-R-4, 2005)
  – Dynamic interaction between Design and Safety Analysis
Safety regulations (risk-oriented)

• The Argentinian regulation does **not foresee restrictive conditions for general cases**. Instead, it is based on **performance or risk-oriented**. This means that it should be guaranteed, for all **postulated accidental sequences** that the **risk on the public** (radiological individual risk) is sufficiently low.

• For each **accidental sequence a probability** (annual occurrence) and a **resulting dose** (effective dose in a representative person) are evaluated.
Safety regulations (risk oriented)

- Each **sequential accident** is represented by a **dot** in this figure.

- For the plant to be **acceptable**, none of these dots must be located in the **non-acceptable zone**
Safety regulations: prescriptive conditions

- The **activation channels** of the shutdown systems must be **redundant**, and if it is possible, **diverses** and designed on at least a 2003 logic.

- The **failure probability** of the **safety systems** must be determined by the **failure tree** technique or equivalent. The **failure rate** per demand for each safety system must be **lower than 10^{-3}**.

- The **global power reactivity coefficient** must be **negative** for all anticipated operational occurrence and accidents.

- The **cooling system** must be designed in such a way that in any operational situation **ONB is not achieved** at any point.

- Specific **suggested** values (ARN guide) for core, experiments and control rods reactivity, shutdown margin, normal and emergency core cooling conditions, fuel storage conditions, etc.
## Design objectives: RI production

<table>
<thead>
<tr>
<th>Application</th>
<th>Spectrum</th>
<th>Flux</th>
<th>Irradiation conditions</th>
<th>Section</th>
<th>Length</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mo-99</strong></td>
<td>Thermal</td>
<td>1.0-1.5 x10^{14}</td>
<td>* Continuous loading</td>
<td>5.2cm (diam.)</td>
<td>30cm</td>
<td>* 10 positions (up to 8 miniplates each one)</td>
</tr>
<tr>
<td><strong>Ir-192 (Industrial)</strong></td>
<td>Thermal</td>
<td>1.0-1.5 x10^{14}</td>
<td>* 2-3 cycles</td>
<td>5.2cm (diam.)</td>
<td>12cm</td>
<td>1</td>
</tr>
<tr>
<td><strong>Ir-192 (medicinal)/Lu-177</strong></td>
<td>Thermal</td>
<td>&gt;2 x10^{14}</td>
<td>* 2-3 cycles</td>
<td>5.2cm (diam.)</td>
<td>12cm</td>
<td>4</td>
</tr>
</tbody>
</table>
## Design objectives: materials irradiation

<table>
<thead>
<tr>
<th>Application</th>
<th>Spectrum</th>
<th>Flux</th>
<th>Irradiation conditions</th>
<th>Section</th>
<th>Length</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural materials irradiation</td>
<td>Fast</td>
<td>$&gt;3 \times 10^{14}$ (E&gt;0.1 MeV)</td>
<td>Rig</td>
<td>5cm (diam.)</td>
<td>12cm</td>
<td>2</td>
</tr>
<tr>
<td>MTR miniplates and fuel elements irradiations</td>
<td>Thermal</td>
<td>$&gt;1 \times 10^{14}$</td>
<td></td>
<td>8x8 cm</td>
<td>65cm</td>
<td>1</td>
</tr>
<tr>
<td>RPV material irradiation</td>
<td>Fast</td>
<td>$1 \times 10^{14}$ (máx), E&gt;0.1 MeV</td>
<td>Rig</td>
<td>5cm (diam.)</td>
<td>12cm</td>
<td>1</td>
</tr>
</tbody>
</table>
# Design objectives: NPP fuel irradiation

<table>
<thead>
<tr>
<th>Application</th>
<th>Spectrum</th>
<th>Flux</th>
<th>Irradiation Conditions</th>
<th>Section</th>
<th>Length</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPP fuel elements irradiation</td>
<td>PWR</td>
<td>1-1.3 x10^{14} (base mode) up to 2.5 x10^{14} (power ramp mode)</td>
<td>* Loop</td>
<td>10cm (diam.)</td>
<td>40cm</td>
<td>1</td>
</tr>
</tbody>
</table>
### Design objectives: NPP fuel irradiation

<table>
<thead>
<tr>
<th>Burnup build-up tests</th>
<th>Transient tests</th>
<th>Selfshielding tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>• base irradiation at constant power</td>
<td>• power ramp with slope 10-50 W/cmmin</td>
<td>• constant power</td>
</tr>
<tr>
<td>• 2 or 3 fuel rods</td>
<td>• 1 fuel rod</td>
<td>• up to 7 fuel rod</td>
</tr>
<tr>
<td>• up to 500 W/cm</td>
<td>• 300 to 500 W/cm</td>
<td>• 200 W/cm.</td>
</tr>
<tr>
<td>• 3 to 5%</td>
<td>• up to 10%</td>
<td>• up to 10%</td>
</tr>
<tr>
<td>• up to 60000 Mwd/tonU</td>
<td>• 2000 Mwd/tonU</td>
<td></td>
</tr>
<tr>
<td>• 3 FPY</td>
<td>• 2 FPM</td>
<td></td>
</tr>
</tbody>
</table>
## Design objectives: neutron beams

<table>
<thead>
<tr>
<th>Application</th>
<th>Spectrum</th>
<th>Flux</th>
<th>Irradiation conditions</th>
<th>Section</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold source</td>
<td>Thermal</td>
<td></td>
<td>$D_2$, cryogenic power &lt; 5 kW</td>
<td>10 lts</td>
<td>1</td>
</tr>
<tr>
<td>Cold beams</td>
<td>$E&lt; 0.01$ eV</td>
<td>$&gt;10^9$ (neutron beams hall)</td>
<td>in-pile guide</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Cold beams</td>
<td>$E&lt; 0.01$ eV</td>
<td>$&gt;4 \times 10^9$ (reactor face)</td>
<td>in-pile guide</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Thermal beams</td>
<td>$E&lt;0.1$ eV</td>
<td>$&gt;10^9$ (neutron beams hall)</td>
<td>in-pile guide</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Thermal beams</td>
<td>$E&lt;0.1$ eV</td>
<td>$&gt;10^{10}$ (reactor face)</td>
<td>in-pile guide</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
### Design objectives: other facilities

<table>
<thead>
<tr>
<th>Application</th>
<th>Spectrum</th>
<th>Flux</th>
<th>Irradiation Conditions</th>
<th>Section</th>
<th>Length</th>
<th>Positions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTD</td>
<td>Thermal</td>
<td>$1 \times 10^{13}$-$4 \times 10^{13}$</td>
<td>With rotator and flatter devices</td>
<td>15.24(2) / 20.32(2) / 25.4(1) cm (diam.)</td>
<td>60cm</td>
<td>5</td>
</tr>
<tr>
<td>NAA</td>
<td>Thermal+Epithermal</td>
<td>$2 \times 10^{14}$</td>
<td>Pneumatic device</td>
<td>3cm (diam.)</td>
<td>12-30cm</td>
<td>1</td>
</tr>
<tr>
<td>NAA</td>
<td>Thermal</td>
<td>$1 \times 10^{13}$ - $2 \times 10^{14}$</td>
<td>• Pneumatic device</td>
<td>3-5cm (diam.)</td>
<td>10cm</td>
<td>12</td>
</tr>
<tr>
<td>Under water NR</td>
<td>Thermal</td>
<td>$&gt; 1 \times 10^{8}$</td>
<td>L/D&gt;150</td>
<td>15cm (diam.)</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Surveillance programme</td>
<td>Reactor</td>
<td>Maximum flux in the reflector Tank</td>
<td>capsule</td>
<td>&lt;5cm (diam.)</td>
<td>12cm</td>
<td>3</td>
</tr>
</tbody>
</table>
General characteristics

- Open pool type
- 30 MW power
- Low enrichment MTR fuel elements
- $D_2O$ reflector
- $H_2O$ moderator - coolant
- Upward coolant direction
- 2 independent shutdown systems: hafnium plates and $D_2O$ reflector tank emptying
- 26 days continuous operation cycle
Core description

- **Compact core with internal irradiation positions:**
  - 19 fuel elements in a 5x5 arrange
  - 2 central positions
  - 4 lateral positions

- **Fuel elements:**
  - MTR type
  - 21 fuel plates, 1.45 mm thickness
  - $\text{U}_3\text{Si}_2$, 0.71 mm thickness meat
  - 565 $\text{U}^5$ g
  - 20 cadmium wires

- **Control rods:**
  - 6 hafnium plates
## In-core facilities performance

<table>
<thead>
<tr>
<th>IRRADIATION POSITION</th>
<th>THERMAL FLUX</th>
<th>EPITHERMAL FLUX</th>
<th>FAST FLUX</th>
</tr>
</thead>
<tbody>
<tr>
<td>CENTRAL</td>
<td>$1.1 \times 10^{14}$</td>
<td>$3.2 \times 10^{14}$</td>
<td>$3.5 \times 10^{14}$</td>
</tr>
<tr>
<td>LATERAL</td>
<td>$2.1 \times 10^{14}$</td>
<td>$1.5 \times 10^{14}$</td>
<td>$1.2 \times 10^{14}$</td>
</tr>
</tbody>
</table>
### Estimated performance for RI production

<table>
<thead>
<tr>
<th>RI facility</th>
<th>Blanket geometry</th>
<th>Irradiation period</th>
<th>Final Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo 99</td>
<td>LEU miniplates</td>
<td>5 days</td>
<td>3000 Ci/w (6- day-Curies)</td>
</tr>
<tr>
<td>Ir 192 (med)</td>
<td>wires</td>
<td>1 cycle</td>
<td>120 Ci/cm (10 Ci/cm seeds)</td>
</tr>
<tr>
<td>Lu 177</td>
<td>foils</td>
<td>1 cycle</td>
<td>90 Ci/g</td>
</tr>
<tr>
<td>Ir 192 (ind)</td>
<td>foils</td>
<td>1 cycle</td>
<td>1900 Ci/g (500 Ci/g )</td>
</tr>
</tbody>
</table>
## Neutron beams performance

<table>
<thead>
<tr>
<th>BEAM TYPE</th>
<th>POSITION</th>
<th>NEUTRON FLUX (n/cm²/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal</strong></td>
<td>TG1, TG2 neutron beams hall (50 mts from reactor core)</td>
<td>$3 \times 10^9$ ($1 \times 10^9$)</td>
</tr>
<tr>
<td></td>
<td>TG3 reactor face</td>
<td>$3 \times 10^{10}$ ($1 \times 10^{10}$)</td>
</tr>
<tr>
<td><strong>Cold</strong></td>
<td>CG1, CG2 neutron beams hall (50 mts from cold source)</td>
<td>$6 \times 10^9$ ($1 \times 10^9$)</td>
</tr>
<tr>
<td></td>
<td>CG3 reactor face</td>
<td>$6 \times 10^9$ ($4 \times 10^9$)</td>
</tr>
</tbody>
</table>
### Preliminary Instrument Proposal

<table>
<thead>
<tr>
<th>COLD NEUTRONS</th>
<th>NEUTRON BEAMS HALL</th>
<th>REACTOR FACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small angle neutron diffractometer</td>
<td></td>
<td>NR</td>
</tr>
<tr>
<td>Triple axis spectrometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflectometer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THERMAL NEUTRONS</th>
<th>NEUTRON BEAMS HALL</th>
<th>REACTOR FACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>High resolution powder diffractometer</td>
<td></td>
<td>High intensity powder diffractometer</td>
</tr>
<tr>
<td>Strength analysis diffractometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGNAA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Loop performance

Test section: 7 UO2 fuel rods, 40 cm length
Coolant: H2O, 18 MPa y 350 °C
Structural material: SS

<table>
<thead>
<tr>
<th>E %</th>
<th>Thermal</th>
<th>Epithermal</th>
<th>Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85</td>
<td>41%</td>
<td>37%</td>
<td>22%</td>
</tr>
<tr>
<td>5</td>
<td>23%</td>
<td>40%</td>
<td>37%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E %</th>
<th>0.85</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total power (kW)</td>
<td>57</td>
<td>145</td>
</tr>
<tr>
<td>Average lineal power (W/cm)</td>
<td>218</td>
<td>560</td>
</tr>
</tbody>
</table>
Conclusions

• The RA-10 project has completed its initial, planning and conceptual stage.

• The proposed design meets the stated objectives.

• The reactor performance must be ensured in the next basic engineering stage, while completing the safety analysis.
Thank you
## RA-10 Project Schedule

<table>
<thead>
<tr>
<th>Id.</th>
<th>TASK NAME</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conceptual Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Contract Negotiation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Basic Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>PSAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Contract Negotiation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Detail Design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Fuel Elements Provision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Fabrication and Installation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Preoperational Tests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Commissioning License</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Commissioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Commissioning Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>FSAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Operation License</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Facilities Commissioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Applications Development Programme</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

International Conference on Research Reactors, Rabat, Morocco, November 14-18, 2011
### SSCs classification

<table>
<thead>
<tr>
<th>System</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Protection System</td>
<td>A</td>
</tr>
<tr>
<td>First Shutdown system</td>
<td>A</td>
</tr>
<tr>
<td>Long Term Cooling system</td>
<td>(A/C)</td>
</tr>
<tr>
<td>Emergency core cooling system</td>
<td>C</td>
</tr>
<tr>
<td>Second Shutdown system</td>
<td>(A/C)</td>
</tr>
<tr>
<td>Confinement Ventilation and Insulation system</td>
<td>(A/C)</td>
</tr>
<tr>
<td>Core</td>
<td>A</td>
</tr>
<tr>
<td>Reflector Tank</td>
<td>A</td>
</tr>
<tr>
<td>Reactor Pool and internal components</td>
<td>A</td>
</tr>
<tr>
<td>Service Pool and components</td>
<td>A</td>
</tr>
<tr>
<td>Reactor Block</td>
<td>A</td>
</tr>
<tr>
<td>Radiation Monitoring System</td>
<td>A</td>
</tr>
<tr>
<td>Neutron Beams</td>
<td>A</td>
</tr>
<tr>
<td>Biological shildings</td>
<td>A</td>
</tr>
<tr>
<td>Cold Neutron Source Vessel</td>
<td>A</td>
</tr>
</tbody>
</table>

A: Safety SSCs  
B and C: Safety related SSCs
## Risk management

<table>
<thead>
<tr>
<th>Event</th>
<th>Mitigation plan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget reduction</td>
<td>To support the project on a wide stakeholders spectrum</td>
</tr>
<tr>
<td>Social oposition during construction</td>
<td>To promote an active and comprehensive communication plan</td>
</tr>
<tr>
<td>No licensing</td>
<td>To implement a Licensing Plan for assuring the inclusion of local regulations and IAEA standards for all the project stages</td>
</tr>
<tr>
<td></td>
<td>To foresee engineering features that might provide from licensing requirements and evaluate its impact in the project</td>
</tr>
</tbody>
</table>
Methodology for safety classification of SSCs

BASIS:

- Defence in Depth Criteria
- Safety function identification
- Consequences of SSCs failure
- Probability of SSCs to be demanded to fulfill a safety function
- Elapsed time after a PIE occurrence in which the actuation of a SSCs is required

ITERATIVE SCHEME SEQUENCE:

1. Postulation of initiating events
2. Safety functions identification (Application of Defence in Depth Criteria)
3. Safety functions Class assignment
4. Requirements per class assignment
5. Safety function groups identification
6. Refinement of class assignment (to Item 3)
Classes for safety classification of SSCs

Class A
SSCs which failure could provoke unacceptable consequences when required
SSCs which failure could provoke unacceptable consequences and there is no class A
SSCs to cope with
Any mitigatory SSCs required to reach a controlled state following a DBE or AOE

Class B
SSCs controlling and limiting relevant process variables
Those SSCs whose failure demands the actuation of a Class A SSCs

Class C
Those SSCs that contributes to ensure class A or B SSCs reliability
Any auxiliary or process SSCs performing mitigation function after a BDBE

Classes Requirements:

• At Function level
• At System Design level
• At Equipment Performance level
• At Quality Assurance, Verification and Mantainance level
# Table of safety Classification of SSCs

<table>
<thead>
<tr>
<th>Structures, systems and components</th>
<th>Safety Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactor Protection System</td>
<td>A</td>
</tr>
<tr>
<td>First Shutdown system</td>
<td>A</td>
</tr>
<tr>
<td>Long Term Cooling system</td>
<td>(A/C)</td>
</tr>
<tr>
<td>Emergency core cooling system</td>
<td>C</td>
</tr>
<tr>
<td>Second Shutdown system</td>
<td>(A/C)</td>
</tr>
<tr>
<td>Confinement Ventilation and Insulation system</td>
<td>(A/C)</td>
</tr>
<tr>
<td>Core</td>
<td>A</td>
</tr>
<tr>
<td>Reflector Tank</td>
<td>A</td>
</tr>
<tr>
<td>Reactor Pool and internal components</td>
<td>A</td>
</tr>
<tr>
<td>Service Pool and components</td>
<td>A</td>
</tr>
<tr>
<td>Reactor Block</td>
<td>A</td>
</tr>
<tr>
<td>Radiation Monitoring System</td>
<td>A</td>
</tr>
<tr>
<td>Thermal Neutron Beams</td>
<td>A</td>
</tr>
<tr>
<td>Cold Neutron Beams</td>
<td>A</td>
</tr>
<tr>
<td>Biological shildings</td>
<td>A</td>
</tr>
<tr>
<td>Cold Neutron Source Vessel</td>
<td>A</td>
</tr>
<tr>
<td>Control and regulation System</td>
<td>B</td>
</tr>
<tr>
<td>Primary circuit</td>
<td>B</td>
</tr>
<tr>
<td>pH /Conductivity Control system</td>
<td>C</td>
</tr>
</tbody>
</table>
Reactor pool and services pool
Reactor pool and services pool
First shutdown system
I&C: neutronic instrumentation system

Nuclear Instrumentation System

Start-up
- Fission Chamber
- 5 Decades
- Connected to RPS.
- Send Data to CMS

Wide Range
- Campbell Fission Chamber
- 10 Decades (5 pulses - 5 fluctuations)
- Connected to RPS.
- Send Data to CMS

Nuclear instrumentation related to SPR
- Train 1
  - Start UP Channel 1
- Train 2
  - Start UP Channel 2
- Train 3
  - Wide Range Channel 1
  - Wide Range Channel 2
  - Wide Range Channel 3

Nuclears Channels Related to RCMS
- Linear Autorange
  - Compensated Ionization Chamber
  - Signal feeds the Automatic Power Control
  - 6 Upper Decades of full power

Nuclear Channels related to FCMS
- Linear N16
  - Gamma Ionization Chamber
  - Complements Automatic Power Control Function
  - Related to Reactor Power Calculation at RCMS

Self Powered Channel 1
Self Powered Channel 2
Self Powered Channel n
I&C: RPS, RCMS, FCMS

CONTROL ROOMS

CMS
- PAM
- RCMS
- FCMS

LCMS

RPS

LPS

NIS

RMS

Process Inst.

Digital Bus

Conventional HVAC

COMMS

Fire

Security

CCTV

Secured HVAC

Service

Nuclear Island

Shutdown Systems

Containment

Processes

CNS

Irradiation Facilities

Beams

LOOP

Plant

NIS: Nuclear Instrumentation System
RMS: Radiation Monitoring System
RPS: Reactor Protection System
PAM: Post Accident Monitoring
RCMS: Reactor Control and Monitoring System
FCMS: Facilities Control and Monitoring System

CMS: Control and Monitoring System
LCMS: Loop Control and Monitoring System
LPS: Loop Protection System
HVAC: Heat, Ventilation and Air Conditioning
CCTV: Close Circuit TV
COMMS: Communications System

CNS: Cold Neutron Source

International Conference on Research Reactors, Rabat, Morocco, November 14-18, 2011