ANSTO & OPAL Research Reactor Overview

Jamie Schulz
OPAL Reactor

- Multi-purpose facility
  - Isotope production
  - Si NTD
  - Materials Irradiation
    - NAA & DNAA
  - Neutron beams
- 20 MW
- Open pool
- Compact core
- D$_2$O reflector
- Plate type Low Enriched Uranium fuel
- Commenced operation 2007
Beams for Neutron Scattering Science
Talks Overview

1. Safety considerations and design principles for research reactor experiments
2. Licensing and regulatory supervision of research reactor neutron beam facilities
3. Operational aspects and management of neutron beam experiments
4. Operational aspects and management of neutron activation analysis experiments
Safety considerations and design principles for research reactor experiments

Jamie Schulz
Outline

• Reactor Safety Classification & Design Principles
• OPAL Utilisation/Experimental Facilities
• OPAL Irradiation Facilities
• OPAL Irradiation Facilities Safety
Reactor Safety Classification & Design Principles

- Application of a systematic approach to determine the safety category, seismic class and quality level of systems, structures and components that is consistent with their importance to safety.

- Application of appropriate codes and standards to systems, structures and components consistent with their safety category and quality level.
Regulations, Codes and Standards

- Application of both local and international codes, standards & practices.
- Adoption of local standards and regulations relevant to the design, construction & modification (ISO, AS/NZ, ARPANSA etc)
- Application of IAEA guides for the design and safety analysis of research reactors, as well as adoption of applicable guidelines from IAEA Safety Guides for nuclear power plants.
- Adoption of appropriate international codes and standards relating to the design of nuclear power plants (IEEE Standards, ASME Boiler & Pressure Vessel Code etc)
Safety Categorisation

• All structures, systems and components of the OPAL reactor are categorised for importance to safety using the following safety categories:

  – Safety Category 1: Any structure, system or component that forms the primary means of ensuring nuclear safety.

  – Safety Category 2: Any structure, system or component that makes an important additional contribution to nuclear safety.

  – Safety Category 3: Any structure, system or component that is not allocated to Safety Category 1 or 2.
Safety Categorisation Methodology

- The methodology by which safety categories were allocated is as follows:
  - The safety functions applicable to the OPAL reactor were identified (about 30) with each safety function being assigned a nominal safety category.
  - The safety functions performed by each system, structure or component were then identified.
  - Each structure, system or component was allocated a safety category consistent with the categorisation of the safety function(s) it performs.
## Selected Safety Functions

<table>
<thead>
<tr>
<th>Safety Function</th>
<th>Safety Function Description</th>
<th>Safety Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>To store and manipulate new and irradiated fuel.</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>To start protective actions in order to shutdown the reactor, to cool and contain radioactive materials, and to mitigate accident consequences.</td>
<td>1</td>
</tr>
<tr>
<td>I</td>
<td>To keep available sufficient quantities of reactor coolant, and/or to remove heat from the core in order to cool it during and after any design basis accident.</td>
<td>1</td>
</tr>
<tr>
<td>M</td>
<td>To limit radioactive material releases from the reactor containment during and after accident conditions</td>
<td>1</td>
</tr>
<tr>
<td>Q</td>
<td>To protect operators during the handling and manipulation of radioisotopes.</td>
<td>2</td>
</tr>
<tr>
<td>S</td>
<td>To provide adequate protection from radiation exposure to operating staff and research personnel, by means such as:</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>a) Shielding.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) Measures and warnings.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>c) Maintenance of sufficient pressure differential between different parts of the containment.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>d) Transport delay to allow decay of radioactive products.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>e) Purification and filtering of the containment.</td>
<td></td>
</tr>
</tbody>
</table>
Seismic Classification

- All structures, systems and components are classified for seismic design requirements using the following seismic classes:
  - Seismic Class 1: Items designed to withstand the ground motions associated with the Safe Shutdown Earthquake (SL-2 level earthquake).
  - Seismic Class 2: Items designed to withstand the ground motions associated with the Operational Basis Earthquake (SL-1 level earthquake).
  - Seismic Class 3: Items designed to withstand the ground motions associated with normal building and industrial codes.
  - Not Applicable: Items for which no seismic analysis applies
Quality Level Allocation

• Structures, systems and components were assigned one of three quality levels (A, B or C) using a systematic assessment process which considers the following:
  – the safety category,
  – the availability classification,
  – the complexity and previous design experience associated with each structure, system or component.

• The quality level determines the quality control and assessment effort to be applied to structures, systems and components during all stages of the project.
## Quality Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Quality Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Inspection and Test Plan</td>
<td>X</td>
</tr>
<tr>
<td>Inspection and Test Plan</td>
<td></td>
</tr>
<tr>
<td>Provision Plan</td>
<td></td>
</tr>
<tr>
<td>Inspection and Test Procedures</td>
<td>X</td>
</tr>
<tr>
<td>Records</td>
<td>A</td>
</tr>
<tr>
<td>Inspection and Test (results)</td>
<td>X</td>
</tr>
<tr>
<td>Non-conformance Control (deviations)</td>
<td>X</td>
</tr>
<tr>
<td>Corrective actions</td>
<td>X</td>
</tr>
<tr>
<td>Qualification of special processes, personnel, etc.</td>
<td>X</td>
</tr>
<tr>
<td>Evaluation of suppliers</td>
<td>X</td>
</tr>
<tr>
<td>Certificate of conformity</td>
<td>X</td>
</tr>
</tbody>
</table>
Design Criteria & Specifications

- The design requirements are specified in the design documentation for all structures, systems and components.
- These specifications reflecting the safety category of the structure, system or component and include, as appropriate:
  - identification of safety functions (category 1 and 2 only) and performance requirements,
  - applicable codes and standards,
  - quality requirements - qualification and materials
  - reliability and safety requirements.
The following OPAL systems/facilities are considered within this group:

- Bulk Production Irradiation Facilities
- Pneumatic Transfer System
  - Neutron Activation Analysis
  - Delayed Neutron Activation Analysis
- Transfer, Loading and Pneumatic Cells
- Large Volume Irradiation Facilities
- Cold Neutron Source
- Neutron Beam Facilities
  - Neutron Beam Instruments
OPAL Utilisation/Experimental Facilities

- Reactor core – in which nuclear fission occurs
- Fuel elements (in core)
- Provision for possible hot neutron source
- Radioisotope and scientific research irradiation facilities (manually loaded)
- Cold neutron source
- Additional neutron beam port
- Heavy water
- Cold neutron beam port

Radioisotope and scientific research irradiation facilities (pneumatically loaded)
Silicon irradiation facilities
Thermal neutron beam port
## Classification of Selected Utilisation Systems

<table>
<thead>
<tr>
<th>System ID</th>
<th>Sub-System ID</th>
<th>NAME</th>
<th>Safety Function</th>
<th>Safety Category</th>
<th>Seismic Class</th>
<th>Quality Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>34</td>
<td>THERMAL/COLD NEUTRON BEAM PRIMARY SHUTTERS</td>
<td>S</td>
<td>2</td>
<td>1</td>
<td>B</td>
</tr>
<tr>
<td>62</td>
<td></td>
<td>COLD NEUTRON SOURCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>30</td>
<td>CNS THIMBLE CONTAINMENT</td>
<td>V1, V2</td>
<td>1</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>68</td>
<td>50</td>
<td>IRRADIATION RIGS</td>
<td>Q</td>
<td>2</td>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>69</td>
<td>50</td>
<td>NAA PNEUMATIC CONVEYOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Containment penetration provisions</td>
<td>M</td>
<td>1</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other equipment and components</td>
<td>-</td>
<td>3</td>
<td>2</td>
<td>B</td>
</tr>
<tr>
<td>69</td>
<td>53</td>
<td>NAA CANS</td>
<td>-</td>
<td>3</td>
<td>N-A</td>
<td>B</td>
</tr>
<tr>
<td>69</td>
<td>54</td>
<td>NAA FUME CUPBOARD</td>
<td>S</td>
<td>2</td>
<td>2</td>
<td>B</td>
</tr>
</tbody>
</table>

S–Radiation Protection, V–protect core, Q–radiation protection handling isotopes, M–Containment Radioactive Releases
OPAL Irradiation Facilities

- Bulk Irradiation Rigs
  - U plate targets for $^{99}$Mo
  - $^{131}$I, $^{192}$Ir, $^{177}$Lu
  - Materials testing (reactor component verification)
- Large Volume Irradiation Facilities (NTD Silicon)
- Pneumatic Facilities
  - Smaller scale radioisotope production
  - NAA/DNAA
General Purpose Pneumatic Facilities

NTD Silicon

Bulk Irradiation Facilities

NAA

DNAA
Irradiations Engineered Safety

- Targets cooled by reactor pool water: ~1.5MW target cooling capacity
  - Flywheels on cooling pumps (gentle coast down on loss of pumps)
    - 2 pumps – 1 on standby
  - Passive target cooling when no pumps running
- A mesh at the top of the rigs protects them from falling objects and prevents coolant channel blockage
- Different rig geometry for different targets to prevent misloading (geometrically safe design)
- Dedicated handling facilities
  - All targets handled under water
  - Hoist speed limited
  - Directly transferred to hot cells
- Automatic reactor power control system designed to compensate for target loading/unloading – shadowing of nucleonics detector
Dedicated Reactor Pool Storage Racks for Irradiation Facilities

- Bulk Rigs
- Neutron Transmutation Doping Very Large
- Neutron Transmutation Doping Medium Size
Service Pool Storage Racks for Irradiation Facilities

NTD Storage Rack

Working Table

Bulk Storage Rack

NTD Storage Rack

NTD Storage Rack
Irradiations Engineered Safety

- Target cans are not opened inside the Reactor Building
- Pneumatics (automated loading/unloading)
  - $\text{N}_2$ used instead of air to minimise dose from $^{41}\text{Ar}$
  - Targets cooled by $\text{N}_2$ during irradiation
  - Only 1 load/unload at a time
  - Automatic unload on high temperature
Irradiations Engineered Safety

- Target containment (1st defence-in-depth layer)
  - Reactor pool/pneumatic system (2nd layer)
  - Reactor building containment (3rd layer)
- Pool water activity monitors (gamma and neutron)
- Automatic containment closure in high stack readings
- Extensive area dose rate monitoring by control room
- Automatic reactor shutdown (trip) on:
  - Target cooling system failure
  - Pneumatic system failure
  - Failure to unload high temp pneumatic target
  - Reactor core high power change rate
Irradiations Administrative Controls

• Administrative procedures to minimise the likelihood of a lightweight small object falling into the pool.
• Control of target materials by administrative procedures and target and canning specifications
• Irradiation authorisation procedures apply
• Administrative procedure to verify coolant flow before rigs loading.
• Procedures to assure safe handling
• Operating Limits & Conditions (OLC’s)
Operating Limits & Conditions (OLC’s)

- Heat limits (reactor cooling system)
  - Power limit (target type dependent)
  - Heat flux limit (target type dependent)
  - Total power limit

Examples:
- Polyethylene pneumatic target 50W
- Aluminium pneumatic target 140W
- U-plate bulk rig 102kW
- Total power limit 1400kW
Operating Limits & Conditions (OLC’s)

• Core reactivity limits – not NAA or DNA (safe shutdown assurance)
  – Limits for “fixed” targets (load/unload with reactor shutdown only)
  – Limits for pneumatic targets (fast unload)
  – Limit on total reactivity worth
  – Reactivity limits:
    • Fixed bulk < 500pcm; non-fixed bulk < 200pcm
    • Pneumatic < 40pcm
    • Total < 3000 pcm

• Mandatory surveillance
Questions....
Licensing and regulatory supervision of research reactor neutron beam facilities

Jamie Schulz
Outline

• Australian Regulatory Framework
• ANSTO Application of Regulatory Framework
• OPAL’s Neutron Beam Facilities
• Recent Modification to Neutron Beam Facility
• Regulation of Neutron Beam Instruments
ARPANS Act 1998

• Objective
  – ‘To protect the health and safety of people, and to protect the environment from the harmful effects of radiation’

• Prohibits certain Nuclear Installations
• Creates the position of CEO of ARPANSA with specific responsibilities
• Establishes committees to advise the CEO
• Provides for regulation of radiation dealings and facility conducts
• Provides a system of licensing for facilities and dealings (prohibitions), with conditions
• Provides powers of inspection, enforcement
• Provide more detailed information on:
  – Definitions;
  – The Council and Committees;
  – Licensing and licence conditions;
  – Reporting by licence holders;
  – Practices to be followed by licence holders;
  – Inspection; and
  – Enforcement.
Regulatory Principles

• Licence holder bears prime responsibility for safety
• Licence holders to be accountable
• Regulatory framework to be efficient and flexible, and based on hazard
• Regulation to reflect international best practice, and
• Consistent with the States and Territories
Roles and Responsibilities

• The licence holder is responsible for:
  – safety; and
  – demonstrating safety to regulator

• The regulator is responsible for:
  – Satisfying itself, parliament, public about safety; and
  – Standard setting, licensing, monitoring compliance, enforcement
Independent Internal Review

• Reactor Assessment Committee (RAC) review of modifications
  – Reviews nuclear safety issues
  – Acts as sub-committee of SAC
  – Does NOT approve modifications but provides recommendations to SAC

• Safety Assurance Committee (SAC) review of modifications
  – Radiation protection, environmental and OH&S issues
  – Approves modifications on basis of its own review and RAC input
Modification Categorisation

- **Relevant Change:**
  - A change to the information contained in the Licence Application
- **Reg 51 Change**
  - Change that as significant implications for safety
  - ARPANSA approval required
  - Cat 1
- **Reg 52 Change**
  - Change that as implications for safety
  - Cat 2
## Classification of Neutron Beam Facility

<table>
<thead>
<tr>
<th>System ID</th>
<th>Sub-System ID</th>
<th>NAME</th>
<th>Safety Function</th>
<th>Safety Category</th>
<th>Seismic Class</th>
<th>Quality Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td></td>
<td>NEUTRON BEAM FACILITIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>21</td>
<td>COLD NEUTRON BEAM + SHIELDS (outside reflector vessel)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Leak detection system</td>
<td>F</td>
<td>2</td>
<td>2</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water retaining boundary (tubes) &amp; seals</td>
<td>I, M</td>
<td>1</td>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Other parts &amp; components</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td>C</td>
</tr>
<tr>
<td>60</td>
<td>34</td>
<td>THERMAL/COLD NEUTRON BEAM PRIMARY SHUTTERS</td>
<td>S</td>
<td>2</td>
<td>1</td>
<td>B</td>
</tr>
</tbody>
</table>

S–Radiation Protection, I–core coolant, F–maintain OLC’s, M–Containment Radioactive Releases
Modification Categorisation

- **Primary shutter**
  - Safety Category 2 system
  - Cat 2 change
  - RAC/SAC Review & Approval
- **Front Cover & LOCA windows**
  - Safety Category 1 system
  - Cat 1 change
  - RAC/SAC Review & Approval
  - ARPANSA Review & Approval
- **Potential Doses (500mSv/hr)**
  - Cat 1 change
- **Submitted all to ARPANSA**
Regulation of Neutron Beam Instruments

• Most instruments at international facilities fall under the facility (reactor) licence

• Argument made that NBI are like an ionising apparatus – “source”
  – When primary shutters are opened they produce radiation
  – Analogy to x-ray device – power turned on
  – Reg 54 - Approval required to construct safety item only applies to controlled facility - does not apply to sources
Overview of licence requirements

CONTROLLED PERSON

CONDUCTS
- Controlled Facilities - Nuclear Installations
- Controlled Facilities - Prescribed Radiation Facilities

DEALINGS
- Controlled Material
- Controlled Apparatus

FACILITY LICENCE
- OPAL Reactor

SOURCE LICENCE
- Neutron Beam Instruments
Regulation of Neutron Beam Instruments

• Separate from OPAL Reactor Licence
  – Experience of operating under HIFAR licence
  – Independence of operations
  – Service Level Agreement
    • Clear lines of responsibility
    • Reactor Operations – up to reactor face (LOCA barrier)
    • Bragg Institute – beyond LOCA barrier
Licensing of NBI’s - 2 stage process

• Plans & Arrangements
• Instruments
  – Hot commissioning source licence – S0171
    • Design approved by ARPANSA
    • Commence hot commissioning of instrument
    • Identify & rectify shielding issues
  – Operational source licence – S0202
    • Updated documentation
    • Demonstrate safe instrument (radiation surveys)
    • Normal operations approved by ARPANSA
Good news since last meeting

- Triple axis (thermal)
- Radiography
- Cold triple axis
- Operating instruments (7)
- Construction/commissioning (7)
Good news since last meeting

SANS Powder (high int.)
Reflectometer
Powder (high res.)
Laue Diffract.
Strain Scanner
SANS2

Operating instruments (7)
Construction/commissioning (7)
Regulatory Supervision

• Planned inspections
• Unannounced Inspections (30 mins notification)
• Quarterly reporting of activities
  – Documentation updates
  – Modification project status
  – Relevant events
• Open, clear communication with regulator
  – Reinforcement of principles
    • Risk, categorisation,
Questions....