Present Status of Australia's OPAL Reactor

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SUMMARY

OPAL is a heavy water moderated, light water cooled, open pool research Reactor, which a thermal power of 20 MW. The core uses MTR type fuel, 20% enriched. The Reactor is located in Lucas Heights, near Sydney.

The aim has been to provide a world class neutron source of great flexibility, high productivity and very high availability. OPAL has been optimized with high priority for neutron beam scattering experiments, and at the same time is provided with a large number of diverse facilities for irradiation experiments, isotope production (Mo^{99} with LEU targets), and Neutron Transmutation of Silicon.

The contract for the design, construction and commissioning of the Australian OPAL Research Reactor was signed between Australian Nuclear Science and Technology Organization, ANSTO (owner) and INVAP from Argentina (designer & constructor) in July 2000, and first concrete was poured in December 2002.

The operation team for commissioning was established during 2004. Since then they have been involved in training and planning and preparation for the commissioning tasks.

Pre-commissioning of equipment commenced with the electrical systems in late 2004.

At present the construction is effectively complete and the authorization to initiate its "Cold Commissioning" was granted by the Australian Regulatory Authority (ARPANSA).

Cold commissioning started as scheduled in early 2006 with the first fuel loading expected to begin in early July 2006, subject to the reception of the operating license.

The oral presentation will highlight the major characteristics of the Reactor and events of the project.

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I. INTRODUCTION

The Australian Nuclear Science and Technology Organisation (ANSTO) has contracted a new high performance Research Reactor – the OPAL Reactor. The Reactor is being designed and built by INVAP (Argentina) at the Lucas Heights Research Laboratories (Sydney) site.

The OPAL Reactor has been optimized with high priority for beam tube experiments, and at the same time is provided with a large number of diverse facilities for irradiation experiments and isotope production.

The OPAL Reactor is a pool-type Reactor featuring a total fission power of 20 MW. It has a compact core of low-enriched uranium fuel surrounded by a heavy water reflector vessel. The Reactor is at the bottom of a light-water filled pool that provides both cooling and shielding to the core.

The design incorporates state of the art technology, high neutron fluxes per unit of power, low fuel costs, two independent shutdown systems, a passive pool for decay heat removal, a containment system for extreme events, and its design is sensitive to operation and maintenance needs.

II. DESIGN ASPECTS

The OPAL Reactor has been designed to deliver a high thermal neutron flux in a large volume outside the Reactor core where it is accessible for experimental use. The concept has been to physically isolate the core from the utilization facilities; thus neither beams nor irradiation facilities are located inside the core itself. This feature permits a better optimization of the neutronic performance of the core and enhances Reactor safety by preventing beam or irradiation activities from jeopardizing the conditions in the core fuel or control elements.

Inside the heavy water reflector that surrounds the core, and coincident with the highest neutron flux densities, are provided several neutron beam tubes, a Cold Neutron Source and positions for material irradiation.

The smaller the core volume, the higher is the neutronic performance of the utilization facilities. The limit on how small the core is has been mandated by a number of constraints, such as: the use of plate type fuel assemblies, the use of low enriched uranium fuel, the target cycle length duration, the removal of decay heat by passive means and the use of a non pressurized primary cooling system.

A. The core

It consists of sixteen fuel assemblies of square cross-section having low-enriched uranium silicide fuel plates with aluminum cladding. The fuel plates incorporate burnable poison to help minimize the core excess reactivity throughout the operating cycle. The core is cooled and moderated by light water and features a heavy water reflector. Fission heat is removed by water circulating through coolant channels between the fuel plates. The Reactor core volume is some seventy litres.

Five control rods are used to control core reactivity. Four have neutron-absorber plates inserted into the core in a cross-shaped array and the fifth has a central cruciform shaped absorber plate. The core is thus divided into four portions of four fuel assemblies each. Table 1 provides the main Reactor data.

Table 1. Main Reactor data

Topic	Value
Reactor type	Open pool
Core thermal power	20 MW
Average core power density	280 kW/L
Core fuel load - BOC	6.25 kg U-235

Average cycle length	29 full power days
Fuel type	19.7% enriched U3Si2-Al dispersion fuel
Fuel assembly residence times	190 full power days
Number of plates per fuel assembly	21

B. Shutdown systems
The Reactor has two mutually independent, redundant and diverse shutdown systems. The action of either of them is capable of shutting down the Reactor and keeping it in a safe shutdown condition during the range of accident events considered in the design as well as some other events of interest.

The First Shutdown System inserts the five control rods into the core by the combined action of gravity and compressed air when requested by the First Reactor Protection System. During normal operation the central control rod is used for reactivity regulation and the other four are used for coarse reactivity compensation, under the control of the Reactor Control and Monitoring System.

The Second Shutdown System partially drains, by gravity, the heavy water from the Reflector Vessel into a storage tank beneath the core when requested by the Second Reactor Protection System.

C. Reactor cooling
The Reactor core is cooled by forced circulation of light water in upwards direction, thus no flow reversal occurs in the transition from forced circulation to natural circulation cooling regimes. In addition other cooling systems remove heat from the reflector heavy water and from the irradiation facilities.

The Reactor Pool Coolant Boundary ensures availability of the water inventory required for core cooling during all foreseeable conditions. If normal electric power is lost the Reactor core and the irradiation rigs are cooled by natural circulation of the pool water. The pool has a sufficiently large water inventory to provide long-term cooling without reliance on external systems or sources of power.

D. Buildings
The facility occupies 13,000 square meters, which includes the Reactor Building built in reinforced concrete housing the Reactor and service systems, the Neutron Guide Hall where the neutron guide systems and the research equipment are located, and Auxiliary buildings, Offices and Cooling Towers.

The Reactor Containment System encloses the Reactor and Service Pools, Reactor Hall, and areas below the Reactor Pool that house Reactor Pool water systems and Reflector Vessel heavy water systems. The Reactor Containment System is designed to prevent or mitigate the uncontrolled release of radioactive materials to the environment.

The facility is divided in zones considering the different tasks carried out within the plant, and taking into account radiation protection, fire protection and security issues. The layout aims at providing each of the different groups interacting with the facility: beam users, Reactor operators, Reactor maintenance staff, radioisotope operations and visitors, with dedicated areas and appropriate circulation paths that allow segregation of their activities. At the same time some strategically placed zones promote interaction between these groups to provide integration.

III. SAFETY PHILOSOPHY
The overall safety objective for the OPAL Reactor is to protect individuals, society and the environment by establishing and maintaining an effective defense against radiological hazards.

Good design practice and construction, including the use of appropriate codes and standards and a quality assurance program, will ensure Reactor safety for normal operation and anticipated abnormal events.

A thorough and comprehensive design, together with operating procedures for the Reactor, will ensure that radioactive releases and the resultant radiation doses are as low as reasonably achievable. The defense in depth strategy has been followed in the design of the OPAL Reactor to compensate for potential human and mechanical failure and unexpected occurrences. Abnormal events are prevented, then mitigated, then accommodated, in that order; and a series of barriers will prevent, reduce or slow down releases of radioactivity into the environment.

The facility meets the regulatory requirements of the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) and complies with applicable International Atomic Energy Agency (IAEA) guidelines and recommendations.

A. Safety concept

The safety of the OPAL Reactor is based on the capability to shut down the Reactor under all circumstances and the prevention of fission product releases by means of successive physical barriers, namely fuel matrix and cladding, pool water and Reactor building. Even in the highly improbable failure of the fuel, the Reactor pool water will retain a large portion of the fission products and the rest will be retained by the containment system.

Engineered Safety Features are provided which are capable of maintaining the Reactor in a safe condition under all anticipated conditions. They constitute the third level of "defense-in-depth' and are designed to prevent incidents from developing into accidents. They comply with fail-safe and reliability safety criteria.

The design incorporates many safety features and inherent safety characteristics. These include:

a) The ability to cool the Reactor by use of natural circulation cooling in the event of loss of normal cooling.
b) The lack of dependence on normal power supplies to shutdown and cool the Reactor.
c) The two diverse and independent shutdown systems. Each employing its own triplicated sensors, logic and actuators.
d) The large volume of low pressure and low temperature water contained in the Reactor pool acts as a heat sink for every relevant accident scenario, this together with the core enclosure and its dedicated Emergency Make Up Water System (EMWS) render negligible the risk of "fuel meltdown" due to exposure to air.
e) An energy management system that ensures that the pressure in the containment remains negative during accident sequences.
f) The levels of protection against loss of coolant accidents.
g) The ability to withstand a 1 in 10,000-year seismic event and beyond and the grille protection against aircraft crash.
h) The low generation of gaseous radioactive emissions due to the use of water cooling of rigs, helium systems in high dose beam areas and a hot water layer at the Reactor pool surface.

B. Safety assessment

The analysis used both deterministic methods and a level 1^+ probabilistic safety assessment. A deterministic analysis of the behavior of the Reactor and associated systems following a comprehensive range of identified Design Basis Initiating Events was performed. All cases analyzed have been conservatively assessed with an assumed single failure of the protection/shutdown systems. The failure of one shutdown system and the need for a Reactor shutdown by the second acting signal have also been assessed. The numerical calculations show that the Reactor goes through a series of safe states following the occurrence of a Design Basis Initiating Event. No significant core or rig damage occurs in any of the assessed transients.

The assessment of individual safety systems was done by means of Failure Mode Effect Analyses.
The core damage frequency of $4x10^{-7}$ per year fully complies with regulatory limits and the selected bounding sequences are well below the frequency-dose acceptance curve.

C. Licensing
Based upon submissions by ANSTO on the site characteristices, and upon constraints ANSTO placed on the design and operation of the facility, ARPANSA issued a Siting Licence in September 1999.

A Preliminary Safety Analysis Report (PSAR), was prepared as part of the Application for a Construction Licence. The development of the PSAR involved INVAP addressing in a comprehensive way the facility's systems and their safety analysis. The PSAR has been prepared in accordance with the IAEA Safety Guide SS 35-G 1 "Safety Assessment of Research Reactors and Preparation of the Safety Analysis Report" 1994. ARPANSA issued a Construction Licence in April 2002.

IV. NEUTRON BEAM FACILITIES
Beams of neutrons are guided to experimental stations outside the Reactor shielding, where they are used as powerful probes of materials.

ANSTO is incorporating into the OPAL Reactor a suite of neutron beam instruments to provide Australia with state of the art capabilities for research in wide ranging fields of science and engineering. The cold neutron source, which is a key element of many facilities around the world, will open new fields of research for Australian scientists.

Neutron supermirror guides are used to efficiently transport neutrons from the high-density neutron areas located in the Reflector Vessel to the research instruments located in the Reactor Beam Hall and the Neutron Guide Hall. Neutron beam facilities include cold and thermal neutron sources, neutron beam shutters, neutron guides and extensive areas for deploying the research instruments.

The buildings that support these facilities comprise:
a) The Reactor Beam Hall (RBH) - an area in the Reactor building that accommodates the neutron beam instruments that need to be as close as practicable to the Reactor.
b) The Neutron Guide Hall (NGH) - an area adjacent to the Reactor building that accommodates the majority of the neutron beam instruments, workshops, laboratories, offices and a viewing gallery.

A. Cold neutron source
The liquid Deuterium type Cold Neutron Source is located close to the peak thermal flux in the Reflector Vessel. It has a maximum neutron yield with energy less than 5 meV, an operating temperature below 25 K, and serves two neutron beam assemblies located on opposite sides of the Reflector Vessel and tangential to the Reactor core. The cold neutron flux at the performance measurement locations at the Reactor face will be of the order of $1.4x10^{10}$ n cm^{-2} s^{-1} and at the performance measurement locations in the NGH will be of the order of $2.7x10^{9}$ n cm^{-2} s^{-1}.

The Cold Neutron Source cooling system is a double-wall liquid deuterium/helium design that promotes reliable and safe operations. Both the Cold Neutron Source cooling system and the Reactor are capable of operation if the other is shut down. Postulated failures of the cold source do not affect Reactor safety. The cold source is automatically monitored and controlled by the Cold Neutron Source Control System.

B. Thermal neutron source

The thermal neutron source comprises a heavy water zone located close to the region of peak thermal flux in the Reflector Vessel and serves two neutron beams located in almost opposite directions and tangential to the core. The nominal thermal neutron flux at the performance measurement locations at the Reactor face will be higher than 1.6×10^{10} n cm^{-2} s^{-1} and at the performance measurement locations in the NGH will be higher than 1.6×10^{9} n cm^{-2} s^{-1}. The neutron spectrum has a temperature in the range 40°C to 60°C.

C. Hot neutron source (future)

On the center of one of the core faces a place has been reserved for the future installation of a Hot Neutron Source (HNS). The envisaged HNS design would be based on a Graphite block heated by radiation coming from the core. It is foreseen that the HNS will operate at a temperature close to 1800 °C. One neutron beam, tangential to the core, originates at the position reserved for the HNS. Until the HNS is installed, the beam will be used as an additional thermal beam.

D. Neutron transport systems

There are five neutron beam assemblies leaving the reflector vessel in a tangential arrangement with respect to the core. Two neutron beam assemblies (one thermal and one cold) deliver neutrons towards the NGH which is located to the north of the Reactor Building. The neutron beam assembly serving the future HNS is directed into the RBH in a westerly direction. The remaining two neutron beam assemblies (one thermal and one cold) leave the Reactor in a southerly direction. The facility layout allows for the future construction of a second Neutron Guide Hall to the south of the Reactor Building. Except for the HNS beam assembly that provides for two neutron guides, all other beam assemblies have capacity for three neutron guides each.

The neutron beams leave the reflector vessel; traverse the Reactor pool liner and the shutters embedded in the Reactor block. The shutters contain sections of neutron guides that penetrate the block to maximize the neutron transport from the core to the experiments.

Neutron supermirror guides are built by sputtering multiple successive layers of titanium and nickel on glass slabs. The guides feature a critical angle of two and three times that of nickel. Guides are contained inside a vacuum housing to ensure optimum transmission and alignment stability.

V. IRRADIATION FACILITIES

Radioisotopes are produced by introducing targets into dedicated irradiation positions in the reflector vessel. Numerous irradiation positions are provided in the reflector tank, some are water-cooled and other are served by pneumatic transport systems. Facilities for irradiation of Silicon ingots for NTD and several hot cells are also provided.

A. General purpose irradiation facilities

They comprise fifty tubes that run from two pneumatic transfer hot cells to locations in the reflector vessel having neutron fluxes ranging from 2.4×10^{12} to 1.0×10^{14} n cm^{-2} s^{-1}

Target materials are loaded into aluminum or titanium containers and are transferred to the irradiation positions in the reflector by nitrogen. There they can remain for periods ranging from seconds to weeks. The nitrogen gas is used both for transport and cooling and consequently targets are limited to those that can be adequately cooled by the nitrogen gas.

B. Bulk production irradiation facilities

They comprise seventeen irradiation tubes running vertically through the reflector vessel. They are water-cooled. Irradiation rigs, which can be removed with the Reactor at power, will accommodate up to five target cans and have a cooling capacity of 125kW. They will be used primarily for the irradiation of low enriched uranium for the production of Mo99, tellurium dioxide for the production of I131 and iridium metal for the production of Ir192.

C. Large volume irradiation facilities

They comprise several irradiation tubes in the reflector vessel that will be used to irradiate mineral and other samples mainly for the minerals industry, and for the neutron transmutation doping of single crystal silicon ingots for the electronics industry. To ensure irradiation homogeneity within the Silicon ingots, they are provided with neutron flux flatteners and are rotated by means of a hydraulic system.

D. Neutron activation laboratory

A laboratory has been provided in the Reactor building for the analysis of samples that are irradiated in large pneumatic conveyor irradiation tubes for only a few minutes. They travel from the Reactor to the laboratory in 3 seconds for immediate analysis of the very short activation products.

E. Neutron transmutation doped silicon laboratory

This laboratory is provided for the post irradiation scanning, cleaning and packaging of the silicon ingots.

F. Shielded hot cells

The facility is provided with four shielded hot cells to allow safe and efficient handling of the radioisotope targets and their delivery to the ANSTOs adjacent radioisotope processing facilities. The irradiated targets are handled as sealed sources within the OPAL Reactor. The total system is designed for the minimum involvement of staff, and for the minimum exposure of those staff that are involved to radiation from the targets being transferred. The design is particularly successful in this latter regard.

Two Pneumatic conveyor hot cells are provided for the transfer of targets from the irradiation tubes to the radioisotope production buildings.

An additional isotope Transfer hot cell is provided for the unloading of the bulk irradiation rigs and for the transfer of the targets removed to the Loading hot cell.

VI. PROJECT MANAGEMENT & ORGANISATION

The construction of the OPAL Reactor represents an important undertaking for INVAP and Australian private companies. Expertise is drawn from INVAP seasoned management and design teams and from strategic associations with the PNPI (Russia) and MIRROTRON (Hungary) for the Cold Neutron Source and the Neutron Guides respectively. INVAP is responsible for the overall delivery of the project that involves the co-ordination of a team of some twelve companies from around the world.

A Project Management Plan (PMP) establishes the overall organizational grounds, responsibilities and links between all the parties participating in the project. The PMP is the key to other general and phase specific plans that are the basis of the project management effort. The project is run under an ISO 9000 certified system, covering design as well as construction activities.

Communication and reporting to the client is done on a regular basis allowing a close control of the project progress and status.

A. Planning and scheduling

The OPAL Reactor project schedule for the OPAL Reactor has a duration of 66 Months. The project is organized through a Work Breakdown Structure (WBS) with more than 300 work packages that cover the different phases: Launching, Preliminary Engineering, Detail Engineering, Construction, Manufacturing and Procurement, Installation, Pre-operational Testing and Commissioning.

The Project Master Schedule (PMS) shows the time frame and precedence for the execution of the different work packages and is an important tool in the planning and control of the project.

The contract for the design, construction and commissioning of the OPAL Reactor was signed in July 2000. This was followed by the completion of the detailed design and an application for a construction license was made in May 2001. The Construction License was issued on 4th April 2002 which was followed immediately by the commencement of the excavations. In Table 2 are indicated the main project milestones.

The project suffered a 4 month delay during the second half of 2002 when two fault strands were discovered during the excavation of the site. A thorough investigation was undertaken using a wide range of techniques and drawing on the expertise of many specialists. These studies demonstrated that there had been no movement of either fault in at least 5 million years and the faults were assessed as incapable. Regulatory approval to proceed with work on the site was subsequently granted.

Table 2. OPAL Reactor Project Milestones

Milestone	Time since project start date
Contract signature	0 month
Presentation of PSAR	10th month
Construction start	21 th month
Construction and installation complete	55 th month
Nuclear commissioning complete	61 th month

B. Risk Management

A Risk Analysis and Management Plan is in place to control, have early warning and allow development of contingency plans to address any technical, organizational or commercial issue that may threaten the project schedule, budget or performance of the final product to be delivered. Relevant actions are taken to provide early detection of any significant change in the risk levels, detect new risks and ensure that tasks and measures are in place to keep risks under control.

C. Local Industry Participation

While INVAP has the overall responsibility for the delivery of the project more than fifty per cent of the OPAL Reactor project will be sourced from within Australia. To this end INVAP has formed an alliance with a large Australian engineering and construction company (John Holland Evans Deakin Industries Joint Venture). Australian companies have participated in the project since the tender and they are responsible for half of the project work packages encompassing engineering, construction and installation activities.

D. Client Participation

ANSTO oversees all the project activities. During design it has participated actively as part of the design teams and in formal design review meetings, during construction it will control the activities by means of nominated witness and hold points indicated in the Construction Inspection and Test Plans.

VII. COMMISSIONING

A. Approach to testing

The initial tests of the OPAL reactor consist of staged test phases identified as post-installation, pre-commissioning and commissioning tests. The post-installation tests commenced with the completion of system/component installation and ended with system turn over for pre-commissioning testing. The pre-commissioning test phase began after completion of the post-installation tests and consisted of individual system tests that finished with the release of the system.

The final set of tests and last phase of the OPAL project is the commissioning phase. This starts with final cold integration tests, followed by loading nuclear fuel and making the reactor critical, measurement of nuclear parameters and successive power raise tests until reaching the reactor nominal power.

INVAP as the principal contractor has the contractual responsibility for commissioning and ANSTO as the operating organisation has the responsibility for operation and maintenance and participates fully in the commissioning process.

B. Commissioning planning

In order to implement the commissioning process, a systematic inspection and testing program has been implemented to demonstrate the performance of all systems, particularly those with a safety function. Therefore, tests of the systems and components of the OPAL reactor are rigorously carried out. Testing is planned and organised in a logical sequence aimed to demonstrate individual system performance and subsequent integration with other plant systems. The Commissioning stages involve a comprehensive series of system integration, fuel loading, power ascension and full power tests, in full accordance with IAEA Safety Guides.

C. Commissioning plans

A Commissioning Plan defines the framework for all of the Commissioning activities and several specific plans (named as Stage A/B/C Specific Commissioning Plan) provide detail on the test procedures and specific arrangements to be observed in each individual stage.

The Commissioning Plan describes the objectives of commissioning and the general activities to be performed throughout the commissioning phase. The commissioning organisational structure is based on the following groups, each having a clear function and responsibility: Commissioning Management group, Commissioning group, Commissioning teams, Construction group, Operations group, Commissioning Safety Review Committee, Commissioning Quality Assurance group.

The Commissioning Group (CG), consisting of the Commissioning Manager (INVAP), the Commissioning Reactor Manager (ANSTO) and the RRR Project Engineering Manager (ANSTO) is responsible for organising the commissioning. The CG meets daily to review and approve the test schedule, procedures, test personnel and start of each test. Commissioning progress is monitored and reports provided to the Commissioning Management Group.

C. Commissioning stages

The Commissioning Plan organises the OPAL commissioning into the following stages:

- Stage A - pre fuel loading tests
- Stage B - fuel loading, approach to criticality and low power tests
- Stage C - power ascension and power tests
- Contract Performance Demonstration Tests

Stage A tests consist of complete system integration tests of the whole plant without nuclear fuel, as well as a verification of the capability of systems. It provides assurance that the plant is ready for fuel loading.

Stage B commissioning commences with the progressive loading of fuel into the core and taking the reactor critical for the first time. This is followed by a series of low power tests aimed at verifying the neutronic efficiency of the shutdown systems and the measurement of a range of neutronic parameters of the core.

Stage C consists of progressively increasing in steps the reactor power up to 100% of full power. This is done whilst performing thermal balance tests and the correlation of thermal power with nucleonic instrumentation and verifying the effectiveness of biological shielding. Following Stage C commissioning the plant is considered to be fully operational.

Contract Performance Demonstration Tests are undertaken to confirm compliance with contract performance acceptance criteria. This involves the measurement of a series of parameters such as neutron flux distribution and spectra within irradiation facilities and neutron guides.

D. Quality management during commissioning

The management of quality during commissioning follows the provisions of the "Commissioning Plan" and "Commissioning QA Plan", and ISO 9000 certification held by ANSTO and INVAP for the OPAL project.

Management of Quality Assurance and Control during commissioning is run by the commissioning quality assurance team, which is coordinated by the INVAP QA Manager for the OPAL project. The team is composed by members both from ANSTO and INVAP.

E. Documentation

Every commissioning test is planned, carried out and controlled using detailed written procedures. The procedures for individual tests are specific in intent, objectives, test instructions and acceptance criteria to be complied with. Test procedures also provide the method for assessing and recording the results of the test.

A total of 108 commissioning test procedures have been issued, 47 covering Commissioning Stage A tests, 39 covering Stage B tests, and 22 covering Stage C tests.

INVAP has the responsibility for issuing the test procedures, which are written by the designers of the various systems. Commissioning Test Procedures are subject to formal review and acceptance by ANSTO.

The test results are registered in the record forms provided in the respective test procedure, which make a Test Record. Where an issue is noted as outstanding during a commissioning test this is indicated in the Test Records.

F. Schedule and arrangements during tests

A schedule for all commissioning stages and also a detailed rolling two-week schedule is kept updated by the Commissioning Manager to allow the planning of the tests and ANSTO participation in them.

In accordance with regulatory requirements ANSTO keeps ARPANSA informed on the schedule of tests.

For each test INVAP nominates a Test Responsible and ANSTO nominates a Lead. Before a given test is started the Test Responsible meets all the test participants and provides a briefing on the test objectives, the overall methodology to be used, and the sequence of steps and actions to be carried out. He also highlights any special precautions to be observed.

While the test is carried out, the Test Responsible directs the execution of the successive test steps in consultation with the Lead person assigned by ANSTO. In order to carry out these tests the main control room is manned by ANSTO operation shift staff who look after the operation of the reactor systems as requested by the test procedures, and are supported by an experienced operations adviser from INVAP.

At the conclusion of the test the Test Responsible and the test participants from ANSTO meet again to review the test results, ensure all record forms are filled and indicate any outstanding items that must be addressed.

G. Processing and approval of test results

Once a given commissioning test is completed the Commissioning Manager and the Test Responsible evaluate the test records and review any outstanding test issue that needs to be closed. The Construction Group is then requested to investigate any outstanding issues and provide a solution. If there is any repair or fix to be carried out the Test Responsible in consultation with the Commissioning Manager and the Construction Group identified the appropriate retesting to be carried out, which is carried out with participation of a witness from ANSTO.

Following completion of a commissioning test and the resolution of any outstanding issues, the Commissioning Manager and the Test Responsible issue a Commissioning Test Approval Sheet for the tests contained in a test procedure. The Test Approval Sheet provides an overall evaluation of the test results includes a reference to the Test Procedure and the Test Record and includes any assessment prepared by the Commissioning Manager, and a conclusion on whether the test objectives have been met or some portion of tests is considered not acceptable and must be repeated. INVAP then issues the test records and test approval sheets to ANSTO for review and final acceptance.

H. The operation licence

The application for the Facility Licence, Operating Authorisation was submitted to ARPANSA in Sept 2004. An Operating Licence is required to enable fuel to be loaded and hot commissioning (Stage B and Stage C Commissioning) and further operation to be carried out.

ANSTO submitted to ARPANSA the SAR, an updated version of the Commissioning Plan and Specific Plans for Stage B and C, together with a schedule of commissioning activities among other documents. A Commissioning Safety Case was prepared by INVAP to provide a safety assessment of the reactor during the commissioning stages and first reactor cores.

Once Pre-commissioning and Commissioning Stages tests were completed, summary reports were issued by ANSTO and INVAP on these Stages in order to provide ARPANSA with an overview of the test carried out and the main outcomes of the tests. These reports providing evidence on the fitness and preparedness of the plant in order to proceed into the following test stage.

The operation license application as a whole, was reviewed by ARPANSA. The application was also open for review by members of the public, and ARPANSA CEO chaired a public forum.

Peer review experts provided by the IAEA have also reviewed the plans and procedures for commissioning. In addition ARPANSA hired an external reviewer to provide an independent assessment of the adequacy of the test procedures to be used during Commissioning Stage B.

On the basis of the evidence provided in the various submissions and reports identified above and in accordance with the requirements of the ARPANS Act and associated Regulations, the CEO of ARPANSA granted the Facility Licence, Operation Authorisation on July 14th 2006. This enabled the fuel to be loaded and the start of Stages B and C of the Commissioning.

I. Testing prior to commissioning

More than 3000 Specific Inspection and Test Plans (SITPs) have been completed to date in OPAL project. Each SITP covers specific construction, manufacturing, installation and pre-commissioning activities.

The Pre-commissioning tests stage alone has required 300 SITPs which address the test requirements spelled in 104 Pre-commissioning Test procedures. Such inspections and tests have demonstrated the performance and safety functions (where applicable) of OPAL plant and equipment. These inspections and tests include factory acceptance tests, site reception tests, installation tests, functional tests and pre-commissioning tests.

VIII. CONCLUSIONS

The Reactor constructed is a world class neutron source of great flexibility, high productivity and very high availability.

The Reactor will also significantly enhance the ability to supply industrial and medical radioisotopes to satisfy the demand into the future. This will be done with a Reactor that has many inherent safety features and very low levels of risk.

The construction started in early April 2002 following the issuance of a Construction License by the Australian Regulator (ARPANSA).

Originally, the reactor should be completed at the end of 2005. The project has some delays due mainly to:

- Unexpected geological features of the selected site
- Increased security expectations
- Regulatory complexities

The present expectation is to have the OPAL reactor at full power at the end of 2006.

On July 14, 2006; ARPANSA (the Australian Regulatory Organization), granted the licence to operate the OPAL Reactor.
The licence was granted following an exhaustive examination of all the evidence presented by ANSTO, including cold commissioning tests. ARPANSA were also advised by overseas consultants, including an IAEA review team – all experts in the field of nuclear reactor engineering.