Replacement Research Reactor Project

OPAL CONSTRUCTION AND STAGE A COMMISSIONING EXECUTIVE SUMMARY REPORT

Prepared By
Australian Nuclear Science and Technology Organisation

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1 INTRODUCTION

The ARPANSA Construction Authorisation for the OPAL Reactor covers four project phases:

1. Detailed Engineering Phase
2. Construction Phase (including civil construction, procurement, manufacture and installation works)
3. Pre-Commissioning Phase
4. Stage A Commissioning Phase

This report summarises the activities conducted under the Construction Authorisation and consists of two substantive sections: Section 2, which summarises the verification processes which were applied to ensure the reactor was constructed in accordance with specified requirements and which have produced the documentation that allows ANSTO to demonstrate this; and Section 3, which summarises the major activities and events which occurred under the Construction Authorisation. Full details of the verification processes and all activities and events are contained in the OPAL Construction Report (RRRP-7033-EBEAN-001) and the OPAL Stage A Commissioning Report (RRRP-7311-EDEIN-004).

2 SUMMARY OF VERIFICATION PROCESSES

The verification processes which were applied to ensure the OPAL Reactor was constructed in accordance with specified requirements are summarised in the following subsections for the Detailed Engineering, Construction, Pre-Commissioning and Stage A Commissioning Phases. These verification processes form part of the Quality Management Systems (QMS) of both ANSTO and INVAP, which are both certified to ISO 9000:2000. The verification processes summarised below are those which have produced the documentation that allows ANSTO to demonstrate that the OPAL Reactor has been constructed in accordance with specified requirements. It should be noted that many other verification processes were also in place throughout the various phases of the project as part of the certified Quality Management Systems, including processes for design change control, non-conformance control, measuring and test equipment control, quality management system auditing, etc.

2.1 DETAILED ENGINEERING PHASE

During the Detailed Engineering phase, the design of structures, systems and components was established through the preparation of design documentation including drawings, specifications, calculations and analyses. This documentation was subject to a thorough review, verification and acceptance process by ANSTO in accordance with project procedures prior to the commencement of construction activities. During the OPAL design phase, over 10,000 detailed engineering documents were reviewed, verified and accepted by ANSTO. In addition, for Safety Category 1 and 2 structures, systems and components, this documentation was used to support requests to ARPANSA for approval to construct items important to safety to meet the requirements of ARPANS Regulation 54 and Licence Condition 4.6. During the OPAL Construction Phase, over 120 approvals to construct were obtained from ARPANSA prior to commencement of construction of items important to safety. Where a relevant change was made which had significant implications for safety, ARPANSA approval was also obtained in accordance with ARPANS Regulation 51 prior to implementing the change.

2.2 CONSTRUCTION PHASE

During the Construction Phase, activities were controlled through the preparation and implementation of Specific Inspection and Test Plans (SITPs), in accordance with the project Construction Inspection and Test Plan (CITP). This verification process was applied to all Construction Phase works, including civil, mechanical / process, electrical, and instrumentation and control systems. Each SITP comprised a sequential list of the activities involved in the performance of a task, including inspection and test activities, specifying for each activity the relevant reference documentation, acceptance criteria, control points and requirements for records/reports generation.

Each SITP proforma used during construction was subject to review, verification and acceptance by ANSTO in accordance with project procedures prior to its implementation. As part of this process, control points, in the form of witness and hold points, were nominated by ANSTO and other relevant organisations, on key SITP activities to ensure that the reactor was being constructed in accordance with specified requirements.

Each SITP included a final inspection/review hold point which was not released until each organisation involved was satisfied that all SITP activities had been satisfactorily completed and documented. Deviations from specified requirements were dealt with through non-conformance control procedures, or, for relatively minor issues, through the generation of punch-lists. These processes ensured that all deviations were appropriately identified, documented and subsequently corrected.

Upon completion of all activities on an SITP and release of the final hold point, the completed SITP, and all supporting records and reports, were compiled into a document termed a History Docket, which forms the final record of the procurement, manufacture, installation and / or construction of an item. During the Construction Phase, around 650 SITP proformas were reviewed, verified and accepted by ANSTO, from which over 2500 individual SITPs were implemented and final hold points released.

Once all SITPs for a system (or in some cases certain parts of a system) were completed, a System Construction Release Certificate (SCRC) was issued listing all completed SITPs involved in construction of the system. SCRCs were signed off by both INVAP and ANSTO, and signified the completion of construction of a system, allowing pre-commissioning activities to proceed on that system. The SCRCs also reference the History Dockets which contain the relevant SITP records.

Once all SCRCs had been issued for those parts of the facility necessary to have been completed in order to commence Stage B commissioning, a Facility Construction Release Certificate (FCRC), listing all of the completed SCRCs, was issued. The FCRC was signed off by both INVAP and ANSTO, and signified the completion of the construction phase as relevant to the commencement of Stage B commissioning. A second FCRC will be issued at a later date to cover the remainder of the facility, but these activities are not required prior to commencement of Stage B Commissioning.

Details on the specific activities to which the SITP process described above was applied for each system, as well as the SCRCs which were issued for each system and the FCRC which was issued for the facility, are contained in the OPAL Construction Report (RRRP-7033-EBEAN-

001). This documentation demonstrates that the reactor has been constructed in accordance with all specified codes and standards, and design, safety and regulatory requirements.

2.3 PRE-COMMISSIONING PHASE

Pre-Commissioning inspection and testing activities were controlled primarily through the preparation and implementation of pre-commissioning test procedures, which describe in detail the activities involved in pre-commissioning of a system, along with relevant reference documentation, acceptance criteria and requirements for records generation. In addition, each pre-commissioning test procedure was accompanied by an SITP used in a similar manner to those of the Construction Phase.

As for the Construction Phase, all pre-commissioning test documentation, including procedures, SITPs and check-sheets, was reviewed, verified and accepted by ANSTO in accordance with project procedures prior to implementation, with control points nominated as required. In general, all pre-commissioning activities were witnessed by ANSTO, with hold points specified at key points to ensure that all requirements were met prior to certain activities proceeding.

Similar to Construction Phase SITPs, each Pre-Commissioning Phase SITP included a final inspection/review hold point which was not released until each organisation involved was satisfied that all pre-commissioning activities had been satisfactorily completed and documented. Processes for documentation of deviations, preparation of History Dockets and issue of system release certificates during the Pre-Commissioning Phase also mirrored those for the Construction Phase, with a System Test Release Certificate (STRC) issued upon completion of pre-commissioning activities for a system, and a Facility Test Release Certificate (FTRC) issued once all relevant STRCs had been issued for the facility.

During the Pre-Commissioning Phase, around 115 pre-commissioning procedures were reviewed, verified and accepted by ANSTO. Two FTRC's have been issued, the first prior to commencement of Stage A Commissioning (at which point about 80% of the pre-commissioning procedures had been completed and released), and the second prior to commencement of Stage B commissioning (at which point about 90% of the procedures had been implemented and released). This second FTRC signifies the completion of the pre-commissioning phase as relevant to the commencement of Stage B commissioning. A third FTRC will be issued at a later date to cover the remainder of the facility, but these activities are not required prior to commencement of Stage B Commissioning.

Details on the pre-commissioning procedures completed for each system, the STRCs which were issued for each system, the FTRCs which were issued for the facility and a summary of the key results obtained during the pre-commissioning activities for each system are also contained in the OPAL Construction Report (RRRP-7033-EBEAN-001). This documentation demonstrates that the reactor has been pre-commissioned in accordance with all specified codes and standards, and design, safety and regulatory requirements.

2.4 STAGE A COMMISSIONING PHASE

Stage A Commissioning was the first of three stages of commissioning planned for the OPAL reactor. It involved testing the facility without nuclear fuel, its objectives being to verify the functionality and performance of safety systems and the integrated functioning of reactor systems.

The overall arrangements for the management of the Stage A Commissioning phase were specified in the overall Commissioning Plan and the Stage A Commissioning Specific Plan.

These plans were prepared by INVAP and reviewed, verified and accepted by ANSTO in accordance with project procedures prior to commencement of Stage A Commissioning.

In June 2004, a request for approval relating to Stage A Commissioning of items important to safety was submitted to ARPANSA to meet the requirements of Facility Licence: Construction Authorisation, License Condition 4.7. This request for approval was based on the above commissioning plans, although it also covered the final commissioning testing of a number of safety-related systems to be undertaken during the Pre-commissioning Phase. In January 2005, the CEO of ARPANSA revised License Condition 4.7 so that it required ARPANSA approval of the Stage A Commissioning program as a whole, rather than requiring separate approvals for the commissioning of the various safety-related items of plant. He also approved the Stage A Commissioning program for items important to safety, provided certain conditions were met during implementation of the program, including a number of ARPANSA control points imposed on specific commissioning activities.

Stage A Commissioning activities were controlled through the preparation and implementation of commissioning procedures for the various systems and subsystems of the OPAL Reactor and overseen by the Commissioning Management Group. Commissioning procedures were prepared in accordance with the commissioning plans, and described in detail the commissioning activities, including the objective of the activities, acceptance criteria, reference documentation, responsibilities, prerequisites, step by step instructions and requirements for records generation. Those commissioning procedures were reviewed, verified and accepted by ANSTO in accordance with project procedures prior to commencement of the relevant commissioning activities. Stage A Commissioning activities were controlled by INVAP, but involved significant participation by ANSTO. This included ANSTO reactor operators performing all plant operations under the direction of INVAP.

During Stage A Commissioning, the Commissioning Quality Assurance Group conducted quality assurance audits of the various commissioning activities, while the Commissioning Safety Review Committee conducted reviews and provided advice on safety issues as requested by the Commissioning Management Group.

A total of 47 commissioning test procedures were implemented during the Stage A Commissioning Phase. Upon completion of all Stage A Commissioning procedures, a Stage A Commissioning report was prepared, providing the final record of the Stage A Commissioning. This report was prepared in accordance with the commissioning plan, and includes a summary of the tests carried out, including reference to the relevant Stage A Commissioning procedures, a description of the limitations, problems or deficiencies observed during commissioning and their resolution; references to data collected, analyses and deviations, and the conclusions and recommendations drawn from the testing. The Stage A Commissioning report signified the completion of Stage A Commissioning, and has been approved by both INVAP and ANSTO.

3 SUMMARY OF KEY ACTIVITIES AND EVENTS

The key activities and events which occurred during the Construction, Pre-Commissioning and Stage A Commissioning Phases of the project are summarised in the following subsections.

3.1 CONSTRUCTION PHASE

The Construction Licence was issued by the CEO of ARPANSA on 4 April 2002. On 8 April 2002, the Acting Director-General of the Australian Safeguards and Non-Proliferation Office (ASNO) advised the CEO of ARPANSA that he was satisfied with the construction site protective security measures. On 10 April 2002, the Minister for Environment and Heritage advised the Minister for Science that he was satisfied with the arrangements covered by the conditions arising from the EIS process relating to the design and construction of the reactor. These approvals allowed construction to commence. Excavation works on the OPAL site commenced on 10 April 2002.

The following subsections provide a summary of the key activities and events relevant to works in the areas of civil works, mechanical systems, electrical systems and instrumentation / control systems during the Construction Phase.

3.1.1 Civil Works

The civil works program commenced with bulk excavation works in April 2002. On 20 June 2002, this work was suspended following the discovery of two geological faults during bulk excavation. A significant geological investigation was undertaken by independent consultants with expertise in fault dating and structural geology, and involved several hundred metres of deep trenching in rock in the immediate vicinity of the excavated site. Those investigations revealed that the faults were not significant in terms of any future seismic events. The suspension of site construction work was revoked on 23 October 2002 following the CEO of ARPANSA's decision that the faulting on the site was not capable of resulting in surface displacement and that there was no change in the basis for his earlier conclusions on the reactor's seismic design.

Construction of the Reactor Building, including construction of the Reactor Building concrete structure and the high density concrete Reactor Block which surrounds the Reactor and Service Pools, took place over the period between November 2002 and February 2005. Concrete pouring activities were strictly controlled, and concrete testing carried out in accordance with relevant codes and standards. The aircraft impact grillage was assembled and mounted on top of the Reactor Building in July 2004. Fit-out and installation of building services proceeded in parallel with and following completion of the Reactor Building structure, including installation of cranes, fire systems, water supply systems, compressed air and gas supply systems and communications systems. Civil works activities were strictly controlled in accordance with the SITP process described in Section 2.2 to ensure compliance with relevant codes and standards, design, safety and regulatory requirements. ANSTO fully participated in this verification process by witnessing key activities, conducting inspections and reviews, and providing final acceptance of the works.

Other facility buildings, including the Neutron Guide Hall and the Main Entry Building, were constructed in parallel with the Reactor Building.

During September 2003, waterproofing problems were encountered at levels -7 and -5 of the Reactor Building due to cracking in the concrete wall and floor slabs. The cracking was caused by concrete shrinkage, coupled with stress concentrations and restraint formed by the foundation rock. Upon detection of the problem, investigations were performed and comprehensive remedial measures were devised and implemented to seal all detected leaks. All remedial works were undertaken in accordance with approved procedures and SITP's. Remedial works have been completed in a significant portion of the affected area with all leaks successfully sealed and released. However, work in a small number of areas has not yet been completed. Whilst waterproofing works in some areas of the Reactor Building are ongoing, the works have no significant effect on the building structure and INVAP and ANSTO have accepted it as fit for purpose.

3.1.2 Mechanical / Process Systems

Construction of mechanical/process systems included manufacture and installation of the Reactor and Service Pools, reactor core components, process piping systems and components, ventilation systems (including containment ventilation and energy removal systems), neutron beam and cold neutron source (CNS) components, radioisotope handling components and radiation shielding components.

The largest single mechanical components to be manufactured were the Reactor and Service Pool liners, the manufacture of which commenced off-site in 2002. In March 2003, manufacture of the Reactor Pool liner was suspended after it was determined that the heavy water penetrations in the bottom of the Reactor Pool liner had been cut out without the approval of the CEO of ARPANSA. In April 2003, ARPANSA granted conditional permission to continue with the manufacture of the Reactor Pool liner with the heavy water penetration cut-outs in the bottom of the liner as is. In May 2003, a non-conformance in the manufacture of the Reactor Pool liner, in which 22 of the wall penetrations were mistakenly positioned due to a manufacturing error, was identified. An investigation was undertaken, and a report outlining the findings of this investigation together with a set of corrective and preventive measures, and an overall strategy for the repair of the Reactor Pool liner incorporating appropriate tests and mock up qualifications, was prepared and submitted to ARPANSA. In August 2003, the CEO of ARPANSA decided that the repairs to the Reactor Pool liner were consistent with his original authorisation to construct that item. The manufacture was then completed, with the liner delivered to the site during December 2003 and installed in January 2004. Manufacture of the Service Pool liner was completed in February 2004 and installed in April 2004 without problems.

Process piping systems and components were manufactured and installed in parallel with construction of the Reactor Building and the Reactor Block. Key items of plant, such as the main primary and secondary cooling pumps, were subject to factory acceptance testing. Reactor core components, including the reflector vessel, control rods, core supporting components, flap valves and Reactor Pool internal piping, were manufactured by INVAP in Argentina and delivered to the site in May 2005. The control rod drives, also manufactured by INVAP in Argentina, were subject to significant factory testing to verify the reliability of their reactor control and shutdown functions. Components such as flap valves and control rod drives were also subject to qualification tests to verify compliance with seismic and operational requirements. Fuel Assemblies were manufactured by CNEA in Argentina, with the first shipment scheduled to be delivered to site in May 2006. The CNS refrigeration / cryogenics equipment was manufactured by Air Liquide in France and was subject to full factory acceptance testing before being delivered to site in May 2004. The in-pile components of the CNS, including the CNS vacuum containment, were manufactured by PNPI in Russia and delivered to site in August 2005.

Manufacture and installation of all mechanical components was strictly controlled in accordance with the SITP process described in Section 2.2 to ensure compliance with relevant codes and standards, design, safety and regulatory requirements. ANSTO fully participated in this verification process by witnessing key activities such as factory acceptance tests, conducting inspections and reviews, and providing final acceptance of the manufacture and installation of systems and components. In particular, ANSTO applied significant resources and expertise to verifying the quality assurance of welding and fabrication processes, to ensure that systems and components were manufactured to a high level of quality in full compliance with relevant codes and standards.

3.1.3 Electrical Systems

Construction of electrical systems included manufacture and installation of electrical switchboards, uninterruptible power supplies and diesel generators, as well as installation of cabling, cable raceways and electrical fittings throughout the facility. Factory acceptance testing was carried out for all switchboards, uninterruptible power supplies and diesel generators. Qualification testing was also performed on switchboards and uninterruptible power supplies to ensure compliance with seismic and other design requirements.

Manufacture and installation of all electrical components was strictly controlled in accordance with the SITP process described in Section 2.2 to ensure compliance with relevant codes and standards, design, safety and regulatory requirements. ANSTO fully participated in this verification process by witnessing key activities such as factory acceptance tests, conducting inspections and reviews, and providing final acceptance of the manufacture and installation of systems and components.

3.1.4 Instrumentation and Control Systems

Construction of instrumentation and control systems included manufacture and installation of the First and Second Reactor Protection Systems (FRPS/SRPS), Post Accident Monitoring System (PAM), Reactor and Facilities Control and Monitoring Systems (RCMS/FCMS), nucleonics instrumentation, radiation monitoring instrumentation and control room consoles, as well as installation of cabling, cable raceways and field instruments throughout the facility. Instrumentation and control systems, particularly those involving software based digital systems, were subject to rigorous verification and validation programs by both the manufacturer and INVAP. These activities culminated in the integrated instrumentation and control factory acceptance test conducted by INVAP in Argentina during 2004. In that test, the FRPS, SRPS, RCMS, FCMS, nucleonics instrumentation and control room consoles were fully integrated and tested before being delivered to the OPAL Reactor site. Radiation monitoring instrumentation was also subject to factory acceptance testing in Argentina prior to shipment. Where necessary, instrumentation was subject to qualification testing to ensure compliance with IEEE standards for qualification of safety-related instrumentation.

Manufacture and installation of all instrumentation and control components was strictly controlled in accordance with the SITP process described in Section 2.2 to ensure compliance with relevant codes, standards, design, safety and regulatory requirements. ANSTO fully participated in this verification process by witnessing key activities such as factory acceptance tests, conducting inspections and reviews, and providing final acceptance of the manufacture and installation of systems and components.

3.2 PRE-COMMISSIONING PHASE

The Pre-Commissioning Phase involved complete testing of the OPAL Reactor facility on a system by system basis. Tests were carried out in accordance with approved pre-commissioning procedures and SITPs, with tests commencing on a system once all construction activities for the system were completed and released. ANSTO participated fully in the pre-commissioning program by witnessing pre-commissioning activities, reviewing pre-commissioning results, and providing final acceptance of systems.

The following sections provide a summary of the key activities and events relevant to pre-commissioning of the various system types: process systems, electrical systems, containment systems, building service systems, instrumentation/control/shutdown systems and radioisotope handling and neutron beam systems. The order of sections follows approximately the order in which pre-commissioning activities were undertaken during the Pre-Commissioning Phase.

3.2.1 Electrical Systems

Electrical pre-commissioning activities commenced in June 2004 with testing of the electrical earthing system and subsequent energisation and testing of the facility's high voltage switchboard and six electrical power transformers. This was followed by energisation and no-load testing of the six Main Distribution Switchboards and the downstream distribution system, including safety-related standby switchboards, motor control centres and distribution boards. No-load pre-commissioning of the distribution system included full functional testing, verification of electrical protective devices and electrical inspections/tests required by Australian Standards and the electrical power supplier, Energy Australia.

Pre-commissioning of the diesel generators commenced in November 2004, and comprised a comprehensive set of starting and loading tests to verify the capability and reliability of the diesel generator units, including a 24 hour full load run test. The tests revealed some problems relating to priming of the diesel generator fuel supply lines, which were rectified by modifying the lines to prevent the occurrence of air pockets in the lines. Following pre-commissioning of the diesel generators, a no-load integration test of the standby power system (SPS) was performed to verify the automatic operation of the SPS to connect the diesel generators on loss of normal power supply (NPS).

Uninterruptible power supplies, including those which supply the FRPS, SRPS, RCMS and FCMS were also subject to full functional testing including loading tests and mains failure simulation tests.

Pre-commissioning of the electrical system culminated in a series of full load system tests conducted in December 2005 once sufficient electrical equipment was available to provide electrical load. These tests verified the operation of both the NPS and the SPS while supplying the full facility electrical load.

3.2.2 Building Service Systems

Building service systems include the radioactive liquid waste management system, compressed and breathing air systems, gas supply systems, water supply systems, fire detection and suppression systems, ventilation and air conditioning systems, cranes and hoists, communications systems, lifts, surveillance CCTV systems and security systems. Each of these systems was subject to one or more pre-commissioning procedures to demonstrate that the operation of the system is in accordance with design specifications and relevant codes and standards. In addition, ASIO T4 will conduct inspections and a performance demonstration of the integrated security system to demonstrate that it meets the specified performance requirements. The ASIO T4 report on security system performance will be transmitted to ASNO and if deemed satisfactory, ASNO will issue a report to the CEO of ARPANSA that confirms the security system is suitable for reactor operation.

3.2.3 Process Systems

Process systems include the primary cooling system (PCS), the reactor and service pools cooling system, the reflector cooling and purification system, the emergency make-up water system, the hot water layer system, the reactor water purification systems and associated resins handling system, the secondary cooling system and the demineralised water supply system.

Each of these systems was subject to a comprehensive pre-commissioning procedure involving testing of all system equipment and verification of system performance. As there was no nuclear fuel in the core during pre-commissioning, fuel assembly dummies were used to simulate the presence of the core. The performance of each process system was shown to meet specified acceptance criteria, with any deviations dealt with through non-conformance control procedures, and supported by additional analysis and testing, where required.

An occurrence of note during the pre-commissioning of the PCS was an event in which the primary cooling flap valves opening time during pump coast down was outside the specified acceptance criteria. In summary, this early opening of the PCS flap valves was determined to be caused by a pressure transient generated by the starting or stopping of secondary cooling system pumps, which was transmitted to the PCS via the heat exchanger plates. As the pressure transient could not be eliminated, additional safety analysis and testing was performed to examine whether early opening of the PCS flap valves compromises the safety of the reactor. The conclusion of that analysis and testing was that the safety of the reactor is not compromised and this was transmitted to the CEO of ARPANSA in May 2006.

Other pre-commissioning testing related to process systems included testing of reactor and service pool internal components. This included testing of the fuel assembly clamps (which clamp the fuel in the reactor core) and testing of the siphon effect breakers (which prevent draining of the pools in the event of a leak in one of the reactor cooling systems). Those tests showed that those components performed as per the design. In addition, leak testing of the control rod drive room, which is designed to be sufficiently leak-tight to contain water in the event of a leak through the reactor pool bottom penetrations, demonstrated compliance with the relevant acceptance criteria.

3.2.4 Instrumentation, Control and Shutdown Systems

Pre-commissioning of instrumentation and control systems included testing of the FRPS, SRPS, PAM, RCMS, FCMS, nucleonics instrumentation systems and radiation monitoring systems. Pre-commissioning of these systems involved testing of the main system functions and verification of all field and control room connections by testing every system input and output for correct operation. In addition, for radiation monitoring systems, radiation sources were used to simulate high radiation conditions in order to verify correct system operation.

Pre-commissioning of shutdown systems included testing of both the First Shutdown System (FSS), designed to shutdown the reactor by rapid insertion of control rods, and the Second Shutdown System (SSS), designed to shutdown the reactor by rapid draining of the heavy water reflector. Pre-commissioning of the FSS involved testing of the control rod withdrawal and insertion times, as well as trip tests including measurement of the control rods' insertion time following a reactor trip for various system conditions. The testing also included verification of the operation of the control rod movement protection interlock, which prevents the simultaneous movement of more than one control rod and limits the control rod withdrawal speed. Pre-commissioning of the SSS included performance tests to measure the rate of drainage of the heavy water reflector following a reactor trip for various system conditions. Acceptance criteria associated with these tests of both the FSS and SSS were satisfied.

An event of note which occurred during pre-commissioning testing of the FRPS and the FSS was a number of spurious actuations of the SRPS and SSS. Investigations determined that this was caused by the control rods bouncing slightly when they were dropped, which in turn resulted in the control rod bottom position indication incorrectly showing that more than one control rod was not fully inserted in the period immediately following the trip. This condition is interpreted by the SRPS as a failure of the FRPS and thus actuates the SSS. To prevent this spurious actuation of the SRPS and SSS, modifications were made to the SRPS instrumentation.

3.2.5 Containment Systems

Pre-commissioning of the reactor containment system included testing of the Reactor Containment Ventilation System (RCVS), Containment Energy Removal System (CERS), Containment Pressure and Vacuum Relief System (CPVRS), and containment isolation system, as well as containment permeability testing.

The RCVS and CERS were subject to several comprehensive pre-commissioning procedures involving testing of all system equipment and verification of system performance. This included testing of the containment pressure control system, which ensures the containment is maintained at negative pressure with respect to atmosphere, and full functional tests including verification of system response to abnormal conditions. Testing of the CPVRS included tests to verify that the system successfully relieves containment pressure in the event of simulated over and under pressure conditions. In addition, pre-commissioning included verification of the efficiency of all particulate and charcoal filters in the facility's ventilation systems. The performance of the RCVS, CERS and CPVRS was shown to meet specified acceptance criteria, with any deviations dealt with through non-conformance control procedures, and supported by additional analysis and testing, where required.

Pre-commissioning of the containment isolation system involved testing of all containment isolation provisions to ensure correct operation in response to containment isolation signals.

In order to verify the integrity of the reactor containment boundary, a containment permeability test was conducted. This test involved pressurising the containment and calculating the permeability based on measurements of the input air flows required to maintain the containment pressure. This test effectively verified that the overall permeability of the containment boundary, including the reactor building concrete structure and its embedded penetrations, the containment air-lock doors and the containment service hatches, was within the safety criterion. In addition, leak tests were performed on individual containment penetrations to verify the correct sealing of containment closures in the event of containment isolation.

3.2.6 Radioisotope Handling and Neutron Beam Systems

Pre-commissioning of radioisotope handling systems involved testing of irradiation rigs and associated process systems, hot cells and associated radioisotope transport systems, and other radioisotope handling equipment. Pre-commissioning activities on these components and systems have not been fully completed; however, their completion is not required in order to commence Stage B commissioning.

Pre-commissioning of neutron beam systems involved testing the CNS and its associated process systems, the neutron beam primary and secondary shutters, the neutron guide helium cooling system and the neutron guide vacuum system. Tests consisted of equipment operation tests and system functional tests. For the CNS this included integrated functional tests with the CNS in-pile thermosiphon connected (without deuterium) including transitions between standby operation (warm) and normal operation (cold) modes with simulated heat load, thermal balance tests and CNS protection and control system tests. Pre-commissioning activities on all these components and systems, with the exception of the neutron guide vacuum system, have been completed, with acceptance criteria satisfied. Pre-commissioning of the neutron guide vacuum system is not required to have been completed in order to commence Stage B commissioning.

3.3 STAGE A COMMISSIONING PHASE

Stage A Commissioning commenced in February 2006, once the Commissioning Management Group was satisfied that sufficient construction and pre-commissioning works had been successfully completed. Stage A Commissioning consisted of a series of facility integration tests, each carried out in accordance with an approved Commissioning Procedure. ANSTO was fully involved in the Stage A Commissioning program through active participation in commissioning activities, and review, verification and acceptance of commissioning results.

The following subsections provide a summary of the key activities and events relevant to the various types of commissioning tests: instrumentation and control systems tests; reactor state tests; containment systems tests; control rooms and emergency preparedness tests; electrical systems tests; CNS tests; facility cold run and health physics tests.

3.3.1 Instrumentation and Control Systems Tests

Stage A Commissioning tests included a group of integration tests on specific instrumentation and control systems, namely the FRPS, SRPS, PAM, RCMS, nucleonics instrumentation and radiation monitoring instrumentation, to verify their functionality. These tests included verification of interfaces with the operators, interactions with the power supply systems and the triggering of protective actions. In addition, instrumentation and control systems were tested concurrently with testing of other systems throughout the Stage A Commissioning Phase, as described in the following subsections. The safety settings of the FRPS and SRPS, as well as set points for automatic RCMS limitation actions, were verified to be as per specified requirements, and the nucleonics instrumentation was verified to be functional through the use of a neutron source. Stage A Commissioning results for instrumentation and control systems demonstrated that the systems are fully operative and integrate in a consistent manner with other plant systems.

One non-conformance report was raised during Stage A Commissioning of instrumentation and control systems. This report covered an event in which the FRPS did not operate correctly due to inhibitions being mistakenly left in the FRPS. Following this event, a full verification of the FRPS hardware and software was undertaken to ensure that no inhibitions or bypasses remained in the system, and the FRPS Stage A Commissioning procedure was repeated in its entirety to verify functionality of the system.

3.3.2 Reactor State Tests

The OPAL reactor has four defined operating states, known as the Power State, Physics Test State, Shutdown State and Re-fuelling State. Each state defines a particular reactor operating environment, with specific rules, interlocks and alarms, as well as requirements relating to configuration of plant systems in order to either allow or preclude the performance of certain tasks.

The bulk of the Stage A Commissioning test procedures involved testing to demonstrate the correct operation of the reactor's safety and plant systems for each of the four reactor operating states. This included verification of the operation of reactor cooling systems, hot water layer system, electrical system, instrumentation and control systems and reactor shutdown systems. As there was no nuclear fuel in the core during Stage A Commissioning, fuel assembly dummies were used to simulate the presence of the core, and nucleonic signals were simulated where necessary. For each reactor operating state, the systems were operated and configured accordingly in order to verify that the reactor's systems are able to perform their assigned functions and that plant parameters remain within acceptable limits. Trial tests of plant operation manual procedures, including those for transitions between the various reactor operating states, were included in this series of tests.

Reactor state tests included coolant flow distribution measurements which demonstrated that the coolant flow rates within the reactor core and irradiation rig positions comply with the specified acceptance criteria. Also, a blocked fuel assembly simulation which demonstrated that this occurrence would be detected by the FRPS instrumentation was performed.

The operation of the PCS flap valves to initiate the transition from forced to natural convection cooling of the reactor core following a reactor shutdown was also tested and found to comply with the specified acceptance criteria.

3.3.3 Containment Systems Tests

Stage A Commissioning included tests of the reactor containment and associated containment ventilation systems in both normal mode and containment isolated mode. The test for normal mode verified that containment conditions, including pressure, temperature and humidity, remained within acceptable limits and that system instrumentation and interlocks relevant to normal mode were functional. The test for containment isolated mode verified the triggering of the various groups of containment isolation closures, the correct operation of containment systems (including the CERS and RCVS) during and following containment isolation, that containment conditions remained within acceptable limits and that system instrumentation and interlocks relevant to isolated mode were functional. The tests demonstrated that the reactor containment and associated containment ventilation systems function correctly.

3.3.4 Control Rooms & Emergency Preparedness Tests

Stage A Commissioning included testing of procedures for evacuation of the Main Control Room to the Emergency Control Centre (ECC) and tests of the operation of the ECC Ventilation and Pressurisation System, which is designed to protect reactor operators from radiation during occupancy of the ECC. An emergency drill was also conducted in order to verify emergency preparedness, including the effectiveness of the reactor systems, emergency plans and procedures, and reactor operations staff in responding to simulated accident scenarios. The results of these tests demonstrated an adequate level of emergency preparedness within the reactor and its operating organisation.

3.3.5 Electrical Power System Tests

Stage A Commissioning included tests to verify the behaviour of the facility following a loss of NPS and to verify the ability of the SPS to provide power to the various reactor systems following loss of normal electrical power. The tests included verification of the effect of loss of NPS on the reactor protection systems, shutdown systems, reactor control and monitoring system, control room consoles and wall panels, heat removal systems, containment and ventilation systems and CNS systems. Also verified was the automatic operation of the SPS in response to loss of the NPS and its ability to supply essential loads including the containment systems, emergency lighting and ventilation, reactor cooling systems and instrumentation and control systems.

3.3.6 Other Stage A Commissioning Tests

Other Stage A Commissioning Tests consisted of an entire facility cold run test, CNS tests and health physics tests.

The entire facility cold run test involved the reactor being operated in Power State at simulated full power for a period of 36 hours, with dummy fuel assemblies in the core, irradiation rigs loaded with dummy irradiation targets, and the CNS and hot cells facilities in operation. The test also trialled procedures for control room shift arrangements and hand-overs, as well as procedures for plant surveillance and in-service inspections. The tests demonstrated that the reactor facility is capable of operating with high availability over an extended period and the plant operating documentation is appropriate. Some tests originally planned for the cold run test relating to operation of irradiation facilities could not be completed due to incomplete installation of some items. However, this did not prevent the test's ability to demonstrate operation of the reactor systems.

CNS tests involved CNS instrumentation and controls systems functionality verification, system manoeuvring tests, and integrated functional tests, similar to those conducted during pre-commissioning, but with deuterium loaded.

Health physics tests conducted during Stage A Commissioning consisted of a health physics walk-through and conducting radiological measurements to provide a baseline on radiation levels prior to fuel loading. The result of the health physics walk-through was that health physics provisions, including radiation shielding, signage, monitoring equipment, personal protective equipment and decontamination facilities are in place and adequate.

4 FINAL CONCLUSIONS

This report has outlined the activities conducted under the Construction Authorisation, including the verification processes applied to ensure the reactor was constructed in accordance with specified requirements and the major activities and events which occurred under the Construction Authorisation. The activities and verification processes completed during the Construction Authorisation have demonstrated that the OPAL Reactor has been constructed in accordance with design, safety, quality assurance and regulatory requirements, and that the facility is in a state suitable for commencement of Stage B Commissioning activities.