Licensing of the OPAL Reactor During Construction and Commissioning

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Abstract. This paper presents a description of the licensing activities associated with the construction and commissioning of the Australian Nuclear Science and Technology Organisation's (ANSTO) OPAL reactor. It addresses the Construction Licence, the interface between ANSTO, INVAP (the contractor with responsibility for design and construction of the facility) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA, the Australian nuclear regulator) during the construction of OPAL, specific licensing issues that have arisen during the construction and commissioning process, and the Operating Licence Application. Particular emphasis will be given to the way in which the licensing process is integrated into the overall project program and the lessons learnt that may be of benefit to other licensees and regulators.

1. Introduction

This paper presents a description of the licensing activities associated with the construction and commissioning of the Australian Nuclear Science and Technology Organisation's (ANSTO) OPAL reactor. It addresses the Construction Licence, the interface between ANSTO, INVAP (the contractor with responsibility for design and construction of the facility) and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA, the Australian nuclear regulator) during the construction of OPAL, specific licensing issues that have arisen during the construction and commissioning process, and the Operating Licence Application. It also address the transition from the licensing regime under the Construction Licence to that under the Operating Licence under which hot commissioning was performed

Particular emphasis will be given to the way in which the licensing process is integrated into the overall project program and the lessons learnt that may be of benefit to other licensees and regulators. It should also be noted that these aspects are all addressed from the point of view of the licensee, ANSTO, and the OPAL Project.

Note that this paper follows on from a paper presented to the IAEA Conference on Research Reactors Safety, Utilisation, Decommission, Fuel and Waste Management in November 2003 [1].

2. The OPAL Construction Licence

The Application for the Facility Licence, Construction Authorisation [2] was submitted to ARPANSA in May 2001. This licence was required in accordance with the ARPANS Act [3] and Regulations [4] in order to commence construction of the Replacement Research Reactor, now formally named OPAL. Following an extensive review process, the CEO of ARPANSA granted the Facility Licence, Construction Authorisation [5] in April 2002. This construction licence authorised ANSTO, via its principal contractor INVAP, to construct the Controlled Facility (i.e. OPAL) on the site defined in the licence. It incorporated 18 Licence Conditions, some of which had significant impact on the construction and commissioning of OPAL, as described below.

2.1. Licence Condition 4.6: Construction of Items Important to Safety

ARPANS Regulation 54 [4] states that "*The holder of a licence, or a person covered by a licence, must not construct an item that is important for safety, and that is identified in a safety analysis report, as part of the construction of a controlled facility, unless the CEO has given the holder, or the person, approval to construct the item*". Licence Condition 4.6 [5] constituted the specific application of ARPANS Regulation 54 within the context of the OPAL Project. It stated that the approval of the CEO of ARPANSA was required to construct the individual items important for safety. It defined "items important for safety" as all the Safety Category 1 and Safety Category 2 structures, systems and components identified in the Preliminary Safety Analysis Report (PSAR, submitted as part of the Application for the Facility Licence, Construction Authorisation) and specified what information needed to be contained in any submissions relating to this licence condition.

This licence condition had a significant impact on the construction of OPAL, due to the number of items that required such approval. The need to demonstrate compliance with Licence Condition 4.6 resulted in a complex process requiring careful control. Therefore, a specific project procedure was developed and the submission process standardised so as to integrate this approval process with both the schedule for the ANSTO review, verification and acceptance of INVAP Detailed Engineering (DE) design deliverables and with the construction schedule.

This meant that in some cases, it became necessary to make multiple submissions for approval for certain systems in order to comply with Licence Condition 4.6, the availability of accepted DE design deliverables and the construction schedule. For example, the Primary Cooling System (PCS) was split across three submissions, one covering the decay tank, one covering the other main components with a significant manufacturing lead time (i.e. the main PCS pumps and heat exchangers), and one covering the remainder of the system. The submissions were done this way because the decay tank needed to be installed very early in the construction schedule, prior to the pouring of the heavy concrete for the Reactor Block and its manufacture involved a significant lead time. As such, approval to manufacture the PCS decay tank was required before all the DE design documentation for the remainder of the PCS completed the required ANSTO review, verification and acceptance process.

During the course of the construction of OPAL, over 130 individual submissions were made to ARPANSA under Licence Condition 4.6. The preparation of such a large number of submissions by ANSTO and their subsequent review and evaluation by ARPANSA imposed a significant workload on both organisations.

This process was not then a one step licensing, nor even a two step licensing, but rather a process of "continuous" licensing. It is probably the right process for one-of-a-kind facilities: the upfront engineering work required for a one step licensing process is probably too large for a single facility, while a two step licensing process would leave too much uncertainty until the submission of the FSAR. Thus, this process helped ANSTO to discuss issues that arose during the detail engineering with the Regulator, and obtain their approval of proposed solutions, without having to wait until the submission of the FSAR.

With hindsight, it would have probably been better to limit the scope of systems to which the Regulation 54 process was applicable. As it was, it applied to every Category 1 or 2 system, in fact encompassing 90% of the plant. For any future project, it could be better to discuss the applicability or not of Reg. 54 system by system with the Regulator, in a similar way as was done for the commissioning (see next paragraph).

2.2. Licence Condition 4.7: Commissioning of Items Important to Safety

Licence Condition 4.7 is an extension of Licence Condition 4.6, and states that the approval of the CEO of ARPANSA was required to commission individual items important for safety as part of the cold commissioning of OPAL. However, in the light of the experience gained in the implementation of Licence Condition 4.6, the CEO of ARPANSA subsequently revised Licence Condition 4.7 such that

it was split into two parts, one covering the overall arrangements for cold commissioning and the other identifying specific systems and components for which detailed information about the commissioning tests was required to be provided to ARPANSA.

As a result, instead of the 130 plus submissions made under Licence Condition 4.6, there was a single submission of the overall arrangements for the cold commissioning, together with the formal submission of specific pre-commissioning and commissioning test procedures as identified by the CEO of ARPANSA. A total of 24 tests were specified by ARPANSA, including those of the first and second shutdown systems, the containment permeability, and the establishment of natural circulation cooling.

3. The interface between ANSTO, INVAP and ARPANSA

For OPAL, the licensee is the Executive Director of ANSTO. However, since ANSTO has a number of controlled facilities, each of which has its own facility licence, a nominee is also identified for each facility licence. For the OPAL construction licence, the nominee was the Project Manager of the ANSTO project management team responsible for the construction and commissioning of OPAL. Within this project team was a dedicated Safety and Licensing (S&L) Manager, whose role was to ensure effective integration of all safety and licensing activities within the project management team and to manage the interface between ANSTO and ARPANSA.

Following the granting of the construction licence, a communication protocol was agreed between ANSTO and ARPANSA that effectively reflected these three levels of management, as summarised in the figure below.

Table 1. ANSTO/ARPANSA Communication Protocol

Level of Communication	ANSTO	ARPANSA
Executive Level	Executive Director	Chief Executive Officer
Management Level	Project Manager	Director, Regulatory Branch
Working Level	S&L Manager, Project Team	Manager, Nuclear Installations

A key part of this protocol was the S&L Manager being the single interface between the project and the regulator at the working level and the resultant working relationship built up between the ANSTO S&L Manager and the ARPANSA Manager, Nuclear Installations. To facilitate this interface, a regular weekly meeting was held between the ANSTO S&L Manager and the ARPANSA Manager, Nuclear Installations at which the INVAP Site Manager and/or Design Manager also attended. The purpose of this meeting was principally to manage the various submissions under Licence Condition 4.6, but it also provided a forum within which any licensing issue could be discussed. This meeting was of considerable benefit in ensuring proper understanding between ANSTO, INVAP and ARPANSA during the development of the detailed engineering design and the construction of OPAL and facilitating the preparation of submissions and their subsequent review and approval.

Both ANSTO and INVAP project managers were also continuously and thoroughly briefed on the status of the licensing process, and when necessary, held separate meetings with the Director, ARPANSA Regulatory Branch. Top management involvement in the licensing process is mandatory in a nuclear project, as the potential impact of the licensing requirements on the project is significant.

4. Licensing issues during construction

As can be fully expected with a project of this type, a number of licensing issues arose during the course of construction and cold commissioning of OPAL. The most significant with respect to their impact on the project are briefly discussed in this section.

4.1. Discovery of a geological fault during site excavations

Civil excavation work began immediately upon receipt of the construction licence in April 2002. However, in June 2002, geological faulting was discovered during the course of the civil excavation work associated with the Reactor Building. ANSTO suspended construction activities on the site, pending the preparation and submission of a report to the CEO of ARPANSA on the nature of the faulting and any implications that it might have for the safety of the reactor if constructed on the site. This report presented evidence that there had not been significant movement of the fault for 9±4 million years and that the fault possibly could be much older.

This finding was assessed against accepted definitions of the capability of faults. As part of this assessment, various aspects were also assessed by various national and international experts. The conclusion of the report that the existence of the faulting did not indicate anything about the general geology of the region that had not been taken into account effectively in the careful seismic assessments that had taken place as a part of the construction licence application and decision was accepted by the CEO of ARPANSA. This event resulted in a delay to the project schedule of four months.

4.2. Concrete cracking in the Reactor Building basement

During the construction of the reactor building, a higher than anticipated level of cracking occurred in the concrete floor and walls of the Reactor Building basement. This cracking was due to a large concrete pour having been carried out on a very hot day in February 2003, resulting in high concrete temperatures from the heat of hydration. As the concrete cooled, concrete shrinkage, coupled with stress concentrations caused by various structural elements such as walls, columns and metal inclusions (junction boxes etc), together with the restraint imposed by rock anchors fixing the building to the foundation rock, led to cracking in the concrete.

The issue was discussed with ARPANSA, which engaged an external civil engineering consultant to provide independent advice. The major issues raised were the efficacy of repairs to the cracking; and the possible long term effects on the integrity of the structure arising from any potential for corrosion of the reinforcing steel and any metal inclusions. ANSTO provide ARPANSA with a report that satisfied ARPANSA staff reviewers about the approach chosen to repair the concrete cracking and that the degradation of the concrete and corrosion of the reinforcing steel from acid groundwater, due to the repaired cracks, is unlikely in the medium to long term. Further, ANSTO advised that a maintenance item would be raised annually for inspection of the concrete crack repairs to be carried out by an external building inspector, who will address the matter of possible degradation of the reactor building structure.

4.3. Reactor Pool heavy water penetration cut-outs

The ARPANSA approval covering the construction of the Reactor Pool liner and welded parts explicitly excluded the cut-outs for the heavy water pipes that penetrated the base of the Reactor Pool. This was because the submission under Licence Condition 4.6 regarding these heavy water penetrations and the associated cut-outs had not been made. However, in the absence of ARPANSA approval, the cut outs were made.

ARPANSA found this to be in breach of ARPANS Regulation 54, in that manufacture of an item important for safety had commenced prior to approval by the CEO of ARPANSA being obtained. However, enforcement action was not taken as it was the first occasion when a breach of licence

condition had occurred and the CEO of ARPANSA was satisfied with commitments made to improve their processes to ensure that that such a breach did not occur again.

4.4. Repairs to Reactor Pool

In early May 2003 ANSTO advised ARPANSA that "*due to a misinterpretation of drawings, the Reactor Pool liner as manufactured to date is not fully consistent with the approved detailed design. Specifically, the locations of a number of penetrations are incorrect*". This manufacturing error actually consisted of various penetration holes in the Reactor Pool liner being incorrectly positioned in some of the liner shell strakes as a result of the strakes being rolled inside out. Of more significance to ARPANSA was the fact that there had been delays in the errors being detected and further delays through the communication chain between the manufacturer and INVAP (the designer) and that unauthorised repairs had been carried out by the manufacturer on some of the misplaced penetrations.

As a result of this issue, ARPANSA imposed an additional licence condition on the construction of OPAL that required ANSTO to provide quarterly reports on quality assurance matters relating to contractors and subcontractors manufacturing Safety Category 1 systems. The licence condition was subsequently revised to include the primary contractors associated with the manufacture of the Cold Neutron Source (CNS) Vacuum Containment and the supply of fuel.

5. The OPAL Operating Licence

The Application for the Facility Licence, Operating Authorisation [6] was submitted to ARPANSA in September 2004 in accordance with the ARPANS Act [3]. It was sub-divided into 5 parts as follows:

- Part A: General information on the purpose and location of the Reactor Facility

This part of the Application contained the Facility Licence Application Form and an overall introduction and description of the facility, its purpose and of the rest of the application.

- Part B: The plans and arrangements for managing safety of the Reactor Facility

This part of the Application contained the various plans and arrangements for managing safety consistent with the ARPANS Regulations [4]. These plans and arrangements related to maintaining effective control, safety management, radiation protection, waste management, ultimate disposal, security and emergencies. In addition, an Environmental Management Plan was also provided.

- Part C: The Safety Analysis Report (SAR) for the Reactor Facility, together with associated safety and licensing documentation

The bulk of the Application was contained in this part in the form of the SAR. This document was based on the PSAR submitted as part of the Application for a Facility Licence, Construction Authorisation, revised to reflect the "as-built" plant and the associated development of the safety case during the construction phase. The SAR will be revised further following the completion of hot commissioning to incorporate the commissioning results.

- Part D: The Operational Limits and Conditions (OLCs) for the Reactor Facility

The OLCs were provided as a separate part of the application since they are mandatory and must be complied with at all applicable times. They were developed using the guidance and format of the U.S. Nuclear Regulatory Commission (USNRC) documentation [7], modified to reflect the specific design and licensing basis presented in the SAR and applicable regulatory processes

- Part E: The plans and arrangements for hot commissioning the Reactor Facility

This part of the Application contained the various plans and arrangements associated with the hot commissioning of OPAL.

The Application was supported by a large volume of documentation, including detailed engineering and analysis reports supporting the SAR, the plant design, operation and maintenance manuals prepared by INVAP and the OPAL Business Management System (BMS). This latter system is a sub-set of the ANSTO-wide BMS and combines all aspects of managing OPAL, including operational, safety and quality assurance aspects, into a single integrated system. Also considered as part of the supporting documentation to the Application were all the submissions made under Licence Condition 4.6 and the results of the Stage A Cold Commissioning.

Following an extensive review process, including a peer review by an IAEA team, the CEO of ARPANSA granted the Facility Licence, Operating Authorisation [8] in July 2006. This operating licence authorised ANSTO to load fuel, perform hot commissioning and operate OPAL. In addition to the Licence Conditions inherent in the ARPANS Act and Regulations, it also identified six Licence Conditions covering periodic safety reviews, periodic security reviews, safety culture, quarterly reporting, discharge authorisations and an index of licensing documentation.

6. Licensing issues during commissioning

As stated above, the granting of the Facility Licence, Operating Authorisation [8] by the CEO of ARPANSA authorised ANSTO to load nuclear fuel and perform hot commissioning. The commissioning of OPAL is discussed in [9]. As is not unusual in the commissioning of a research reactor, which, by definition, is of a unique design, a number of issues and events arose during hot commissioning, of which the more significant in relation to licensing are discussed below.

6.1. ARPANSA Hold Points

Hot commissioning of OPAL was split into stages as follows:

Stage B1: First fuel loading and initial criticality

Stage B2: Low power physics test under natural circulation cooling

Stage C: Power ascension and full power test under forced circulation

At the request of the CEO of ARPANSA, hold points were incorporated at the end of each of these stages at which a commissioning report was prepared summarising the results of that stage's commissioning tests. The relevant commissioning stage report was submitted to the CEO of ARPANSA, who then gave approval for ANSTO to proceed to the next stage.

This issue was not anticipated during the initial scheduling of the commissioning program. However, due the preparation of the relevant commissioning reports in parallel with the commissioning testing and the efficient review of these reports by ARPANSA (assisted by the presence of ARPANSA during all the actual commissioning tests), the resultant delays to the commissioning schedule were not significant.

6.2. Core outlet temperature and core temperature difference measurements

During measurements at 10 MW in Stage C Commissioning, it was observed that the core outlet temperature and the core temperature difference as measured by the temperature sensors located in the control rod guide box fastener (CRGBF) were providing values lower than the values provided by other temperature sensors located elsewhere throughout the Primary Cooling System. Given that the core outlet temperature and the corresponding core temperature difference should vary proportionally with the reactor power, the prediction of the reactor power as obtained through other methods, including the nucleonics instrumentation and thermal balance, was investigated. This showed that the

power as calculated using the core temperature difference was significantly lower than the values obtained by the other methods.

A number of causes were investigated and it was determined that the most likely cause was a downwards flow of cooler pool water along the inside of the CRGBF leg that resulted in a localised cooling phenomenon of the temperature sensors located at the bottom of the CRGBF leg. An interim seal was placed on the upper end of the CRGBF leg, closing the openings that allowed water to flow downwards through the leg and reach the temperature sensors, and further testing performed. This testing showed significant improvements in the performance of the temperature sensors but not to the extent anticipated. Further analysis indicated that the flow resistance through the bottom of the CRGBF leg where the temperature sensors were located also had an impact. This was due to the relative large size of the tubes housing the temperature sensors in relation to the size of the flow path through the CRGBF leg.

On the basis of the testing and the additional analysis performed, a formal design modification to the CRGBF was prepared and submitted to ARPANSA under ARPANS Regulation 51 (i.e. a relevant change with significant implications for safety). This change consisted of sealing the CRGBF leg to minimise any flow down the inside of the leg and improvements to the flow path through the bottom of the CRGBF leg (by reducing the size of the tubes housing the temperature sensors). This was quickly approved by the CEO of ARPANSA, facilitated by working level meetings at which ARPANSA officers were regularly briefed on the status of the investigation and the proposed resolution such that they were familiar with the submission when it was finally made. The modification was then implemented and measurements made at several power levels demonstrated that the new temperature sensor arrangement is adequate and that the readings were in accordance with calculated values.

6.3. High Activity within Primary Coolant

Following a reactor start-up after refuelling, instrumentation showed a continuing rise in activity levels in the Primary Coolant System. Such increases in the activity levels in the primary coolant following refuelling are normally indicative of either a potentially failed fuel assembly or the presence of “tramp uranium” contamination on the surface of one of the new fuel assemblies.

Appropriate operational measures were implemented to address this issue, including increased monitoring of the primary coolant activity levels and operating at reduced power levels. Tests were performed to determine the specific cause of the increasing activity levels in the primary coolant flow, including sampling of each quadrant of the core. These test indicated that the source was located in the SW quadrant (core positions A1, A2, B1 and B2), and individual sipping of the fuel assemblies in these positions indicated that fuel assembly ASR 003 in position A2 was suspect.

A submission was made to ARPANSA under ARPANS Regulation 51 requesting a variation to the approved fuel management strategy to replace this suspect fuel assembly with a new fuel assembly. This submission was approved by the CEO of ARPANSA, again facilitated by working level meetings at which ARPANSA officers were briefed on the investigation such that they were familiar with the submission when it was finally made, and the revised fuel management strategy implemented.

7. Conclusion

Licensing activities during construction involved significant effort on the part of the licensee ANSTO, the contractor INVAP and the regulator ARPANSA, particularly as a result of Licence Condition 4.6 imposed as part of the construction licence. Licensing activities during commissioning also involved significant effort on the part of all three organisations. A number of lessons can be learnt from the experience gained during the construction of OPAL that may be of use to other potential licensees and vendors.

The primary lesson learnt is that good communication between the licensee and the regulator, aided by regular meetings providing a forum within which licensing issues could be discussed, is of considerable benefit. Such a forum also provides an excellent means of keeping the regulator informed during the course of resolving safety and licensing issues that arise during the course of construction and commissioning. It also enables the regulator to more readily understand, and thus review and approve urgent submissions made in response to events during construction and commissioning.

The working level communication should be the main contact point between the regulatory body and the licensee, and should be managed through a single interface from each side, minimising the possibility of misunderstandings. However, it is important that this communication is also established at different levels: operating level, project management level, and executive levels. However, these other levels of communication should not impair or replace the main contact point at working level, but rather complement this principal interface when necessary.

It is also important that the communication channels between the licensee, the regulator and the contractor (where appropriate) be in place early in a project so that all parties have a clear understanding of the project and what is expected from them in relation to the successful completion of such projects.

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