OPAL COLD NEUTRON GUIDE IN-PILE REPLACEMENT

T. ROWNES*, A. ELTOBAJI, M. BELL, F.KLOSE
Nuclear Operations, ANSTO, New Illawarra Rd,
2234 Lucas Heights – Australia

*Corresponding author: timothy.rownes@ansto.gov.au

ABSTRACT

The 20 MW_{th} OPAL research reactor has five neutron beam assemblies. These provide cold and thermal neutrons to various neutron guides and associated neutron beam instruments. In 2010 a project was initiated to install a new cold neutron guide, CG2, in one of the assemblies. This installation would allow up to four new neutron beam instruments to be built, significantly expanding the reactor's capabilities. The project concluded in December 2012 with the successful installation of CG2.

Each neutron beam assembly has an in-pile plug, a primary shutter and a front cover. Together these constitute the neutron guide's in-pile components, with a total mass of over 12 tonnes. The CG2 installation required the complete replacement of the existing components. This replacement was scheduled to coincide with OPAL's first major shutdown.

With a budget of $2.3 million and an expected dose of 50 man.mSv, the CG2 installation was a large and complex task. Work during the shutdown involved over 40 ANSTO personnel and radiation fields approached 1 Sv/h in some areas. Despite this, the installation team received a collective dose of only 10 man.mSv, and the project was completed to budget and within schedule.

This paper will outline the details of the project, focusing on lessons learned and recommended practices. Each OPAL in-pile plug has a design life of 10 years at full power operation, and similar replacements will be performed regularly as the reactor ages. It is hoped that this information will be useful for other research reactors planning large capital engineering projects.

1. Project Background

1.1 Purpose

OPAL is a 20 MW_{th} research reactor operated by the Australian Nuclear Science and Technology Organisation (ANSTO). The reactor was commissioned in 2006 with capacity for up to 18 neutron beam instruments. During the following years nine new instruments were constructed in the first neutron beam instruments program. In 2009 the Australian Government granted ANSTO $37 million for a second neutron beam instruments program. A major part of this program would be the upgrade of one of the reactor's existing cold neutron beam assemblies. This would deliver a new split guide, Cold Guide 2 (CG2), in between the existing CG1 and CG3 guides and allow capacity for up to four new instruments. Serious work began on the CG2 installation project in 2010.

OPAL's five neutron beam assemblies are built into the reactor block surrounding the reactor pool. Neutrons travel out from the reflector vessel through beam tubes and are collimated by the assemblies. The CG1-3 assembly is shown in Figure 1.

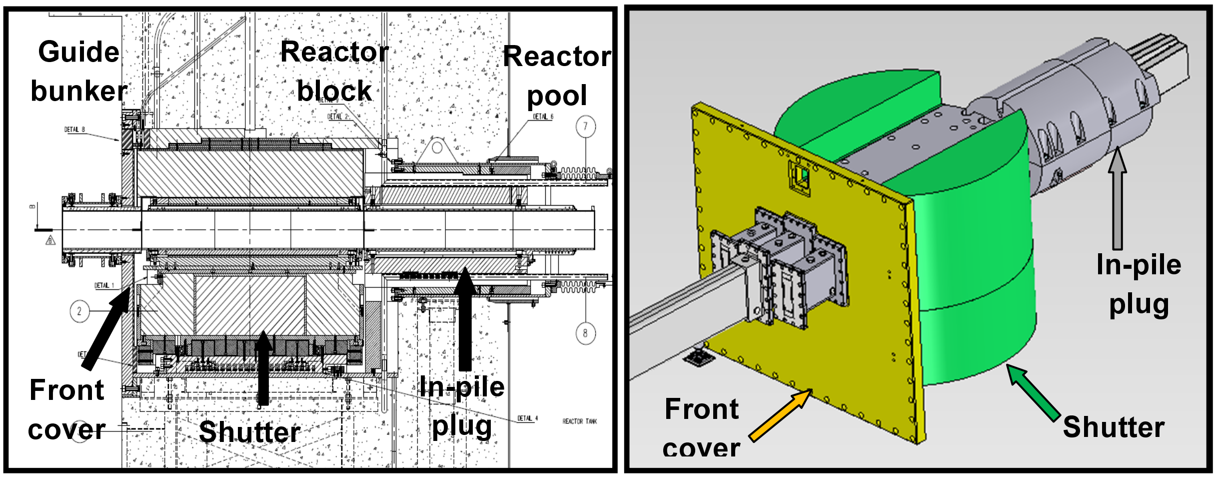

Fig 1. Neutron beam assembly CG1-3 cross-section and components

Normal reactor operation makes the neutron beam assemblies radioactive and ages their materials. In addition, the high neutron and gamma flux in the beam tube causes degradation of the guide glass in the in-pile plug. For this reason each in-pile plug has a design life of approximately 10 years. Therefore, although the purpose of the CG2 installation was to deliver the new split guide, it also served as a test case for future in-pile plug replacements.

1.2 Outcomes

The CG2 installation was successfully completed during one six-week outage in November-December 2012. All training and preparations were completed in time, and the project was completed within budget. The installation team received a collective dose of 10 man.mSv; 5 man.mSv below the expected dose. The highest dose received by an individual was less than 1 mSv.

2. Scope

2.1 Affected Systems

The installation had minimal impact on other reactor systems. Most importantly the reactor core was defueled for the duration of the outage for maintenance and inspection work to be performed within the reactor pool. This meant that removal of the front cover, which forms a secondary barrier to a loss of coolant accident, had no safety implications. Defuelling also reduced dose rates in the guide bunker to manageable levels with the shutter removed; however, access was sometimes restricted in nearby areas due to elevated radiation levels. The high-purity helium cooling system for the CG1-3 assembly was also isolated and vented for the installation.

2.2 Technical Description of the New Equipment

The new equipment comprised the guide glass, the in-pile plug, the shutter, and the front cover. The old and new equipment are almost identical except for the added guide, as shown in Figure 2.

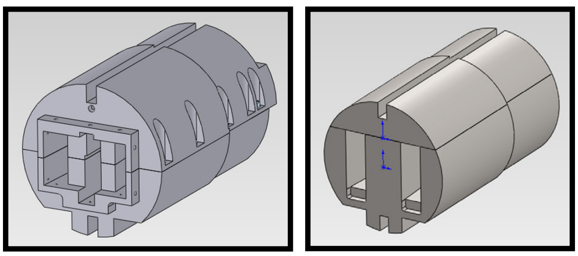

Fig 2. New in-pile plug with CG2 (left) and old in-pile plug (right)

The in-pile plug collimates the neutron beam and receives the majority of the neutron and gamma flux. It is made of low-Cobalt, zinc-coated steel with a mass of approximately two tonnes, and is installed and removed using a dedicated in-pile shielded cask provided as part of the reactor's original equipment (OE). The guide glass and in-pile plug were supplied by SwissNeutronics of Klingnau, Switzerland.

The shutter provides shielding when closed and opens to allow neutrons to pass. It is made of alternating layers of low-Cobalt, zinc-coated steel and polypropylene. This combination provides effective shielding from both neutrons and gamma radiation. The shutter is the largest of the in-pile components, with a mass of approximately 9 tonnes. The new shutter was installed using a dedicated shutter shielding cask provided as OE, and the irradiated shutter was removed with an identical cask fabricated specifically for this project. Both the shutter and the in-pile plug are installed using a roller rail system. This allows a very tight tolerance of ± 0.05 mm in the guide glass position.

The front cover seals the helium atmosphere of the neutron beam assembly. It is made of aluminium and lead and has a mass of approximately one tonne. The shutter and the front cover were fabricated by Williamson Tool and Engineering of Sydney, Australia.

2.3 Safety and Licensing

The CG2 installation was assessed to be a modification with significant implications for safety due to the design change to the secondary LOCA barrier. As such, it required a detailed submission to Australia's nuclear regulator ARPANSA for approval. To facilitate this process, ANSTO made two submissions for the project: one for design and manufacture and another for installation and commissioning. As per the OPAL change control process, both submissions were reviewed by two internal safety review committees (the Reactor Assessment Committee and the Safety Assurance Committee) to assess the implications for nuclear safety and worker safety. Vendor information suggested the expected dose for the installation was 50 man.mSv, so the most visible factor for worker safety was radiation. Detailed planning and training allowed the project team to set a reduced dose target of 15 man.mSv. The regulator gave approval for the installation one week before the planned outage.

3. Required resources

3.1 Budget

The budget for the project was $2.3 million. An approximate cost breakdown is shown in Figure 3.

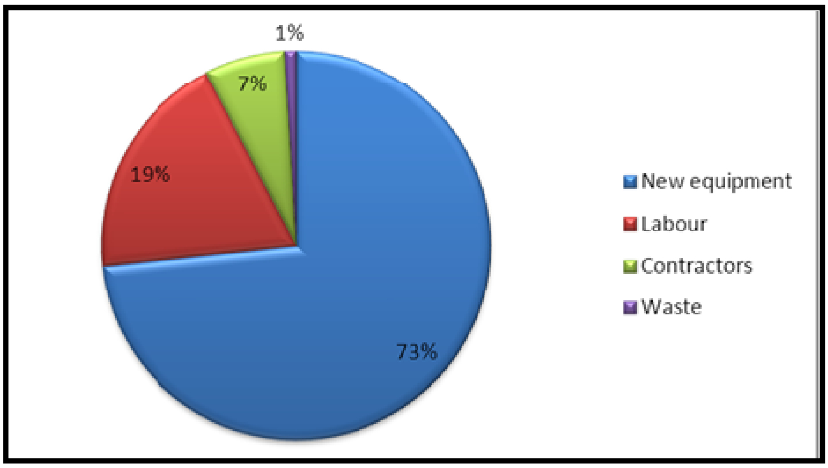

Fig 3. CG2 cost breakdown

3.2 Project team

ANSTO currently employs over 1000 staff on one site in various groups, including Reactor Operations, Waste Operations, Human Resources, Engineering and Capital Programs, and the Bragg Institute which operates the neutron beam instruments. The project was managed by the Bragg Institute, with support from Reactor Operations and Engineering and Capital Programs. Progress was overseen by a major shutdown oversight committee, made up of senior managers and technical experts from various ANSTO groups, including the Chairs of the two ANSTO safety committees.

An implementation team of engineers, technicians and a scheduling contractor was formed six months before the installation to prepare tools and processes. This team included a specialist trainer from Reactor Operations who performed a training needs analysis and subsequently planned and conducted training.

During the installation over 20 staff worked full-time on the project in shift teams. Each shift team included six technicians led by two supervisors; a representative from Human Resources; a health physics surveyor and a radiation protection advisor. Human resources were involved to provide support from the team meeting room and act as an interface between the shift teams and the rest of ANSTO.

3.3 Contracted staff

Several contractors were involved in the project. Two contractors from Blue Visions, a Sydney management consulting firm, provided assistance with project management and scheduling. Two Swiss Neutronics personnel travelled to ANSTO to install and align the guide glass. In addition, four specialist logistics contractors moved the irradiated, 16 tonne shielded shutter from the reactor building to the low level waste facility.

4. Management

4.1 Planning

The installation was planned internally using established ANSTO project management processes. Contractor support for planning was used very effectively. The project team created detailed schedules for preparation work, as well as an installation schedule using estimated times for each activity. The installation schedule was integrated into the overall shutdown plan in order to track progress of the entire outage.

4.2 Implementation

Implementation involved two phases: preparation and installation. Preparation took place during the six months leading up to the major shutdown. This was a very busy and demanding period for the implementation team, who worked regular overtime to meet deadlines. Training formed a very important part of preparation, and the team set up a training area to replicate the guide bunker and neutron beam assembly. This area was also used to prepare the new components for installation, as shown in Figure 4. As a result of training, tools and processes were improved and the installation instruction was revised and refined.

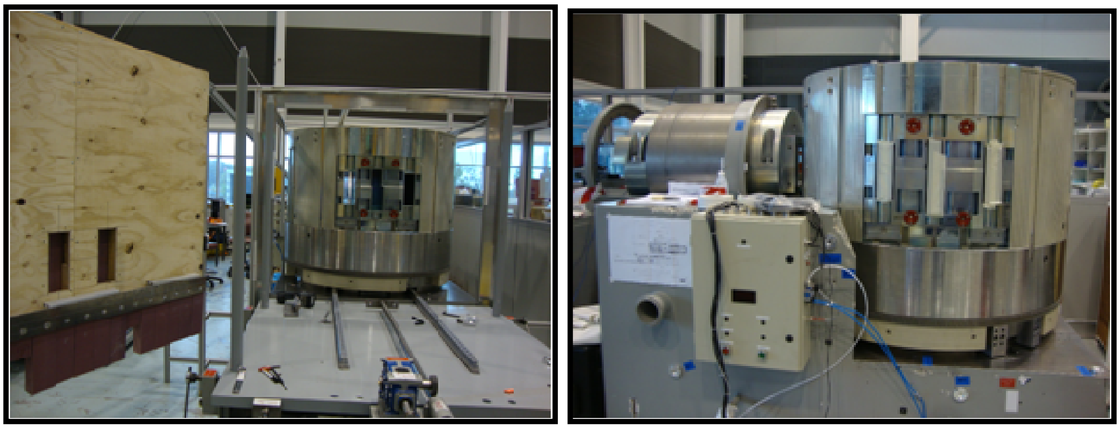

Fig 4. Shutter and in-pile shown in the training area

During the installation two shift teams worked in 8.5-hour shifts with 30 minutes for handover, allowing 16 hours of work per day. The shifts kept detailed logs and progress was tracked against the schedule on a daily basis. Technicians worked with long tools behind mobile shielding, time in certain areas was limited and dose was shared throughout the team. In addition, the entire installation was recorded on video for future reference. Once the installation was complete, the instruction was revised again using feedback from staff involved in the installation process.

4.3 Risk management

The project risks were assessed and documented in an overall risk management plan. The oversight committee reviewed and acted upon these risks on a weekly basis. Major risks included delays in regulatory approval, late delivery of equipment, incomplete preparation, and higher than expected radiation fields. Technical risks were also assessed and documented prior to implementation. The implementation team used strategies to minimise these risks, including building redundancy into the shift teams and creating plans to deal with failed components.

4.4 Interface with stakeholders

The major shutdown oversight committee also managed the interface with stakeholders, including the regulator, customers and ANSTO staff. The regulator was kept informed of progress, and contingency plans were made for communication with customers in the event of an extended reactor outage. Information about the project was posted on site-wide intranet and progress reports were made at staff forums.

5. Lessons Learned

5.1 Removal and storage of waste

The reactor was built with a storage facility for degraded in-pile plugs; however, in this case storage was not straightforward. During the installation, the irradiated in-pile plug was found to be stuck in the neutron beam assembly. Unfortunately the roller rail system included some plastic components that had degraded into powder. Instead of a planned removal by hand, the in-pile had to be dragged out with an improvised lever hoist. Once removed, the in-pile plug also had to be mechanically displaced into the storage facility. The roller rail failure also filled the neutron beam assembly with hundreds of tiny roller bearings that had to be vacuumed out. These activities delayed work by several shifts. Similar failures are now expected for all the current in-pile plugs.

The highly-activated in-pile plug was stored in one of the reactor's dedicated storage facilities. The shutter is designed to be reusable after decay and was moved to temporary storage in a low level waste facility at ANSTO. The front cover was not highly activated and was stored near the in-pile plug behind minimal shielding. All other waste was stored in ANSTO's on-site low-level waste store.

5.2 Recommended practices

The three key lessons learned from the project are as follows:

- Create a core team to develop tools, instructions and processes. The implementation team had strong ownership of the project and worked hard to make it succeed

- Draw on all available expertise. The project team involved staff from across the whole of ANSTO. For example, shift team members were nearly all volunteers and came from many ANSTO groups. This gave them very broad knowledge and access to tools and equipment from different groups.

- Communicate effectively. Effective communication by the oversight committee ensured all levels of ANSTO understood the project's priority and allocated resources accordingly.

6. Acknowledgements

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