SUSTAINABLE MANAGEMENT OF AUSTRALIAN RESEARCH REACTOR SPENT FUEL

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ABSTRACT

Since the late 1950s ANSTO has successfully operated three research reactors in Australia: HIFAR (1958-2007), Moata (1961-1995) and OPAL (2006-present). ANSTO has always been committed to the safe, secure and sustainable management of spent fuel.

Australian research reactor operating licenses have required the identification of spent fuel disposition arrangements. The deferment strategy (indefinite storage) has not been acceptable. HIFAR and Moata fuel has been dispositioned via three routes; direct disposal in the USA under the US-DOE FRRSNFA program, reprocessing in France by AREVA and reprocessing in the UK by the UKAEA. Both reprocessing routes included the return of vitrified waste.

In recent years ANSTO has been working to finalise a management strategy for OPAL spent fuel. OPAL fuel consists of low enriched uranium silicide (U_3Si_2) clad in aluminium. The reprocessing of U_3Si_2 presents technical challenges. AREVA recently overcame these challenges and offered ANSTO an integrated spent fuel management solution including transport, reprocessing and waste return. ANSTO has now entered into a contract with AREVA to manage OPAL spent fuel until 2030. Both parties expect to extend the contract beyond 2030 to provide effective spent fuel management for the life of OPAL. ANSTO and AREVA are now working closely to finalise arrangements for the first shipment of OPAL spent fuel in 2018.

1. Introduction

The Australian Nuclear Science and Technology Organisation (ANSTO) is the home of Australia's nuclear science expertise and landmark scientific infrastructure, including a synchrotron, accelerators, cyclotrons, the Open Pool Australian Light-water (OPAL) research reactor, and associated neutron beam instruments. ANSTO is an Australian Government agency that has been operating research reactors since the late 1950s. ANSTO is responsible for the safe, secure and sustainable management of its spent fuel.

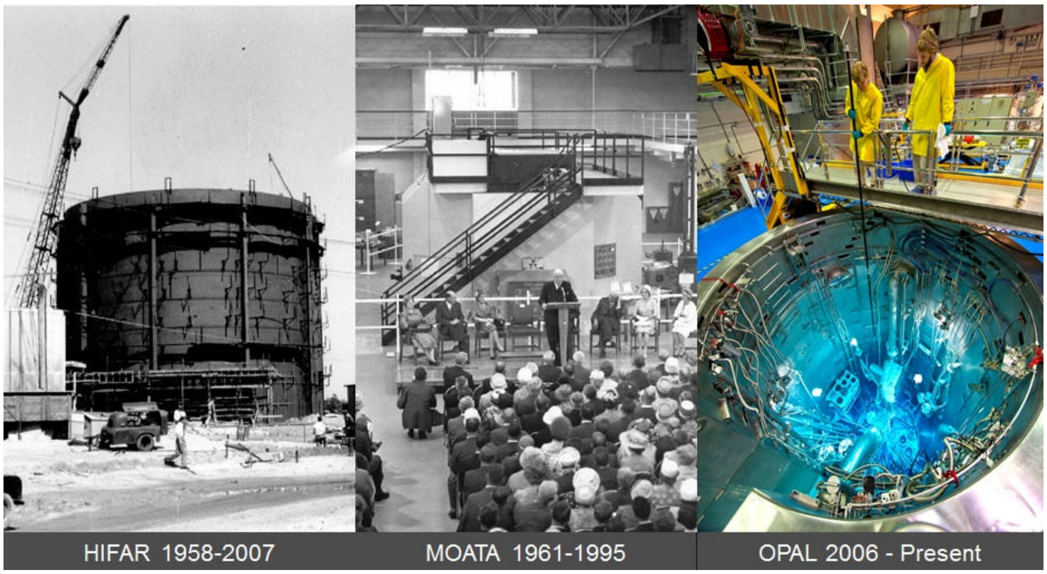

Figure 1: Australian research reactors

Research reactor spent fuel presents challenges because the aluminium cladding degrades and renders the fuel unsuitable for very long term storage or ultimate disposal. Over the past decades ANSTO has gained valuable experience in the management of research reactor spent fuel, including its storage, transportation and reprocessing.

For the HIFAR and Moata reactors, ANSTO has previously implemented management strategies in conjunction with international service providers including France (AREVA), USA (US-DOE), and the UK (UKAEA). In recent years ANSTO has assessed available options for the management of OPAL spent fuel and in 2016 ANSTO entered into a contract with AREVA to provide an integrated solution for the management of OPAL spent fuel.

This paper provides a brief history for HIFAR and Moata spent fuel management, and outlines the process leading to the selection of AREVA for the management of OPAL spent fuel. The paper also discusses plans for the first shipment and reprocessing campaign for OPAL spent fuel. Finally, plans for the return and management of residual intermediate level waste (ILW), resulting from reprocessing, are summarised.

2. Previous Spent Fuel Management

2.1 HIFAR Spent Fuel Management

HIFAR was a 10 MW DIDO class reactor, operating between 1958 and 2007. During nearly 50 years of operation 2281 spent fuel assemblies were generated. HIFAR commenced operation with HEU assemblies enriched to 93% U-235. It used fuel assemblies enriched to 80% U-235 for most of its operating life before conversion to LEU in 2006.

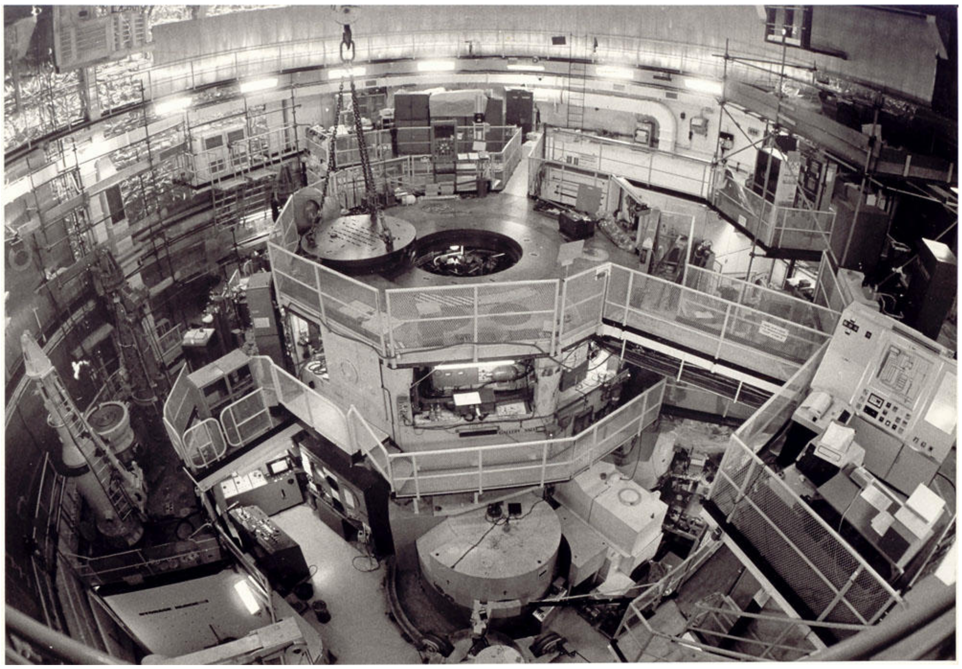

Figure 2: the HIFAR top plate, circa 1980

Australia's strategy for the management of HIFAR spent fuel has evolved in response to external influences. When HIFAR was commissioned it was envisaged that all spent fuel would be reprocessed in the UK or the US. One shipment of 150 spent fuel assemblies was made to the UK in 1963 with an agreement for no return of residual ILW. Australia then initiated planning for nuclear power and domestic reprocessing. Further shipments were abandoned in favour of on-site storage with a view to reprocessing once a facility had been constructed. In the late 1970s it became clear that Australian nuclear power and reprocessing was unlikely. On-site storage continued while overseas options for spent fuel disposition were evaluated.

The enriched uranium in HIFAR fuel was of UK and US origin and this influenced the selection of disposition arrangements. In 1998 240 HIFAR spent fuel assemblies containing US origin uranium were shipped to the US Savannah River Site (SRS) under the US Foreign Research Reactor Spent Nuclear Fuel Acceptance (FRRSNFA) program. An extension of the FRRSNFA program to 2016 allowed shipment of the remaining US origin HIFAR spent fuel in two shipments of 316 and 159 fuel assemblies, completed in 2006 and 2009 respectively. No waste was returned to Australia under this program.

In 1996 114 HIFAR spent fuel assemblies with uranium of UK origin were shipped to Dounreay, UK for reprocessing. Plans were underway for an additional four shipments, however, in 1998 the UK government decided to cease all commercial reprocessing. Following the UK decision ANSTO entered into contracts with the French organisation COGEMA (now AREVA) for the transport, reprocessing and return of residual ILW for the remainder of the HIFAR spent fuel assemblies stored at ANSTO. A total of 1288 HIFAR spent fuel assemblies were shipped to the La Hague, France reprocessing facility in four shipments in the years 1999, 2001, 2003 and 2004. In 2015 the residual ILW from the reprocessing of these assemblies was returned to Australia (refer to Section 7 for details).

The ILW resulting from the UK reprocessing of the 114 spent fuel assemblies shipped in 1996 is scheduled to be returned to Australia in approximately 2021. A change to UK legislation in 2012 permitted vitrified waste to be substituted for the originally proposed cemented waste. This significantly reduced the volume of the ILW to be transported and stored.

2.2 Moata Spent Fuel Management

Moata was a 100 kW Argonaut type reactor, operating between 1961 and 1995 using HEU fuel assemblies of US origin. Moata was initially used for research and training and was later also used for neutron activation analysis, neutron radiography, soil analysis and cancer treatment research.

Figure 3: Moata reactor

Moata Decommissioning was completed in 2010. Spent fuel was unloaded in 2005 and the 2006 shipment of 316 spent HIFAR spent fuel assemblies included 14 Moata spent fuel assemblies. That is, in 2006 a total of 330 spent fuel assemblies were shipped to the US under the FRRSNFA program.

2.3 Shipment Summary

Table 1 below shows all ANSTO spent fuel and ILW return shipments, including the planned ILW return in approximately 2021. The experienced gained in managing HIFAR and Moata spent fuel has helped ANSTO to establish a safe, secure and sustainable management plan for OPAL spent fuel.

1963	UK	150 FA
1996	UK	114 FA
1998	US SRS	240 FA
1999	COGEMA	308 FA
2001	COGEMA	360 FA
2003	COGEMA	344 FA
2004	COGEMA	276 FA
2006	US SRS	330 FA
2009	US SRS	159 FA
Dec 2015	AREVA	ILW Return
~2021	UK	ILW Return

Table 1: Australian spent fuel and ILW return shipments

3. OPAL Spent Fuel Management Strategy

3.1 OPAL Reactor Background

The OPAL reactor is a 20 MW open pool type research reactor. It is light water cooled and moderated and has a heavy water reflector. OPAL is primarily used for the production of nuclear medicine, neutron beam science and for the production of neutron transmutation doped (NTD) silicon which is used in high power electronics.

OPAL fuel assemblies are 1045 mm long and 80.5 mm square in cross section. OPAL uses low enriched uranium silicide (U_3Si_2) dispersed in aluminium. The cladding is aluminium 6061. The fuel was initially manufactured by INVAP (Argentina), but since the resolution of a fuel fault in 2008 it has been manufactured by AREVA-CERCA (France). ANSTO discharges 27-30 spent fuel assemblies per year.

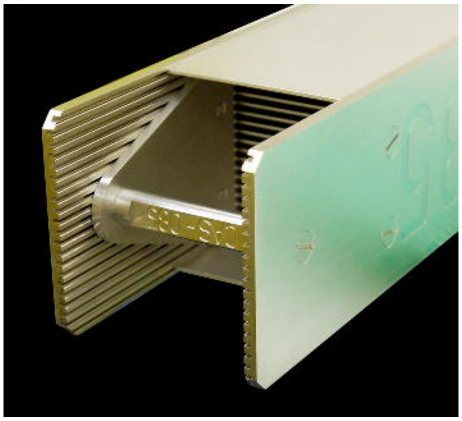

Figure 4: OPAL fuel assembly

3.2 US-DOE Spent Fuel Management Option

In recent years ANSTO has investigated various options for the management of OPAL spent fuel. In accordance with operating licenses the indefinite storage of spent fuel in Australia is not acceptable.

ANSTO first considered shipments to the US under the US-DOE FRRSNFA program. Due to the ending of the FRRSNFA program this option would only cover spent fuel removed from the reactor core by May 2016. The spent fuel would have to be received in the US by May 2019. Although the disposal of OPAL spent fuel in the US with no return of ILW was an attractive option, the ending of the FRRSNFA program meant that it would only be an interim solution and ANSTO would have to develop a second disposition route for all spent fuel removed from the reactor core after May 2016.

3.3 France-AREVA Spent Fuel Management Option

Due to the complexities and inefficiencies associated with having to plan for two disposition routes, ANSTO looked for an alternative solution and initiated discussions with AREVA. The reprocessing of uranium silicide fuels has previously presented technical challenges because high concentrations of silicon are not compatible with the PUREX process. However, AREVA recently overcame these challenges.

After uranium silicide spent fuel is dissolved in nitric acid, and before the solvent extraction process starts, the solid silicon and fines are separated from the aqueous solution by centrifugation. The silicon and fines are set aside and later incorporated into the final vitrified ILW waste-form. AREVA has submitted an application to the French Safety Authority (ASN) to commence the reprocessing of uranium silicide fuels in 2017.

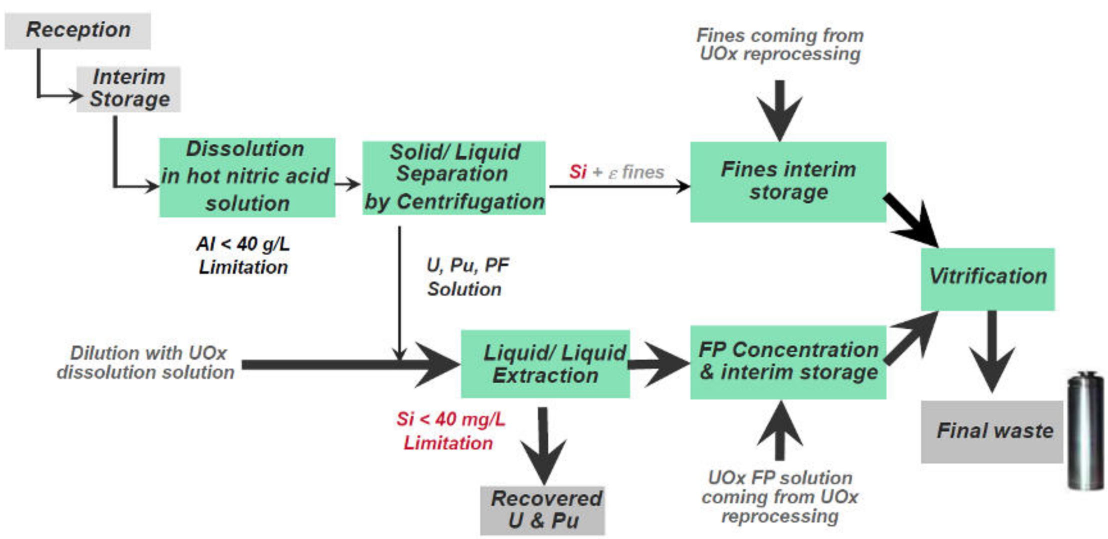

Figure 5: Process schematic for reprocessing of OPAL spent fuel at AREVA La Hague

In addition to this reprocessing, AREVA offered ANSTO transportation services covering the transportation of spent fuel to France. The AREVA solution was attractive because it offered a simple, integrated solution for the life of OPAL. It also offered cost savings and one less spent fuel shipment when compared to a solution incorporating shipments to the US under the FRRSNFA program.

The AREVA solution was also beneficial because ILW would be returned as a vitrified waste-form, which is highly stable, compact and easily stored over long periods of time. AREVA guaranteed the long-term availability of its transportation services and La Hague facilities. After careful consideration ANSTO accepted the AREVA offer and a contract was executed mid-2016.

The first OPAL spent fuel shipment to France is scheduled for mid-2018. Shipments will occur every 6-7 years thereafter. The first return of Intermediate Level Waste (ILW) resulting from the reprocessing of OPAL spent fuel is scheduled to occur 2035-2040. In total, it is expected there will be 2 returns of ILW for the design life of OPAL.

4. International Agreements

4.1 Uranium and Plutonium Transfer of Title

The AREVA reprocessing of OPAL spent fuel is subject to the conditions of a transfer of title agreement between ANSTO and AREVA. During the early stages of reprocessing the title of the plutonium and uranium in the spent fuel will pass from ANSTO to AREVA, with the concurrence of the Euratom Supply Agency. The safeguards provisions in the agreement stipulate that the uranium and plutonium can only be used for peaceful purposes. The uranium and plutonium extracted from OPAL spent fuel will be used by AREVA to fabricate mixed oxide (MOX) and enriched reprocessed uranium (ERU) fuel, which will be used in the civil nuclear power program. That is, OPAL spent fuel will have a “second life”, being used to generate electricity.

4.2 Inter-Governmental Agreement

According to a European Directive and French Law, the introduction of spent fuel to France has to be framed by an Inter-Governmental Agreement (IGA) between the French and Australian Governments. The IGA is currently being finalised. It outlines a schedule for the receipt and reprocessing of OPAL spent fuel. It also details the planned use for the materials separated during reprocessing. Finally, article L542-2 of the French Environmental Code specifies that the disposal in France of radioactive waste originating from abroad is forbidden. This includes waste arising from the reprocessing of spent research reactor fuel. The IGA includes a requirement for the ILW resulting from reprocessing to be returned to Australia.

5. TN-MTR Procurement

OPAL spent fuel will be transported to AREVA, La Hague using AREVA TN-MTR type spent fuel transportation casks. A TN-MTR cask can hold up to 68 OPAL spent fuel assemblies. The casks meet the requirements of the IAEA Regulations for the Safe Transport of Radioactive Material and Australia’s nuclear regulator, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) has recently validated the use of TN-MTRs in Australia.

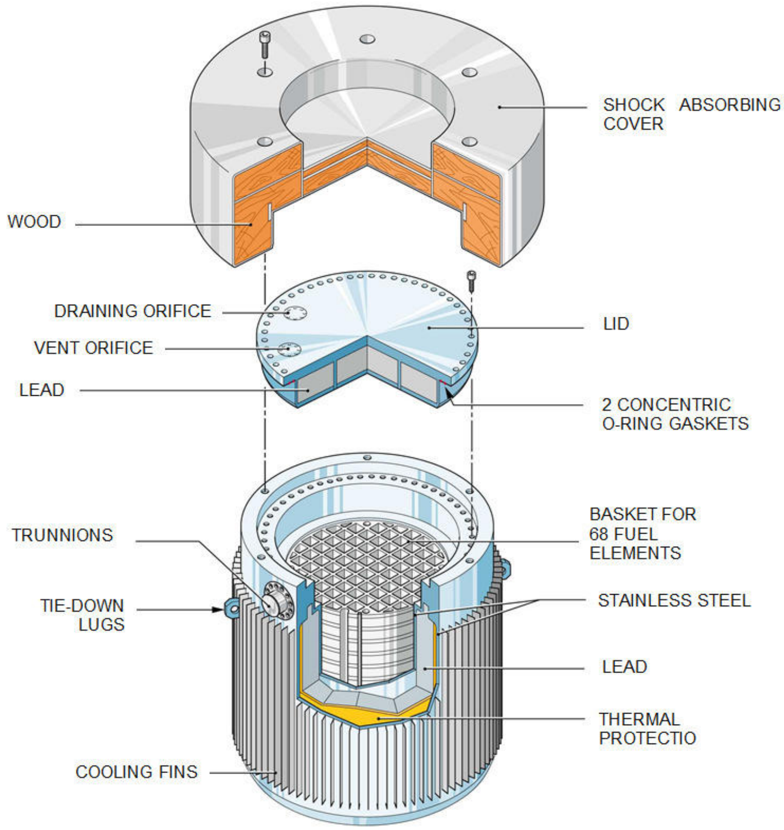

Figure 6: AREVA TN-MTR spent fuel transportation cask

The first OPAL spent fuel shipment to La Hague will utilise four TN-MTR casks. ANSTO is hiring three casks from AREVA and will purchase the fourth from AREVA. ANSTO decided to purchase its own TN-MTR for risk mitigation. The continued operation of OPAL is vital for the supply of nuclear medicine around the world. Great importance is also placed on high reactor availability for neutron beam science and the production of NTD silicon. In the event that a spent fuel shipment is delayed and ANSTO runs out of space for the storage of spent fuel, a TN-MTR could be used for interim storage, subject to regulatory approval, which will enable the continued operation of OPAL. The fabrication of ANSTO's TN-MTR is currently in progress.

6. Operations at ANSTO

The OPAL reactor was designed with the intention of loading spent fuel with minimal disruption to operations. The OPAL reactor consists of two pools; the circular Reactor Pool (RPO), which contains the core and heavy water reflector vessel with irradiation positions, and the rectangular Service Pool (SPO), which is connected to the RPO and is used for the storage of various items and spent fuel. The fuel assembly storage rack in the SPO has the capacity to store spent fuel resulting from approximately 10 years of OPAL operation.

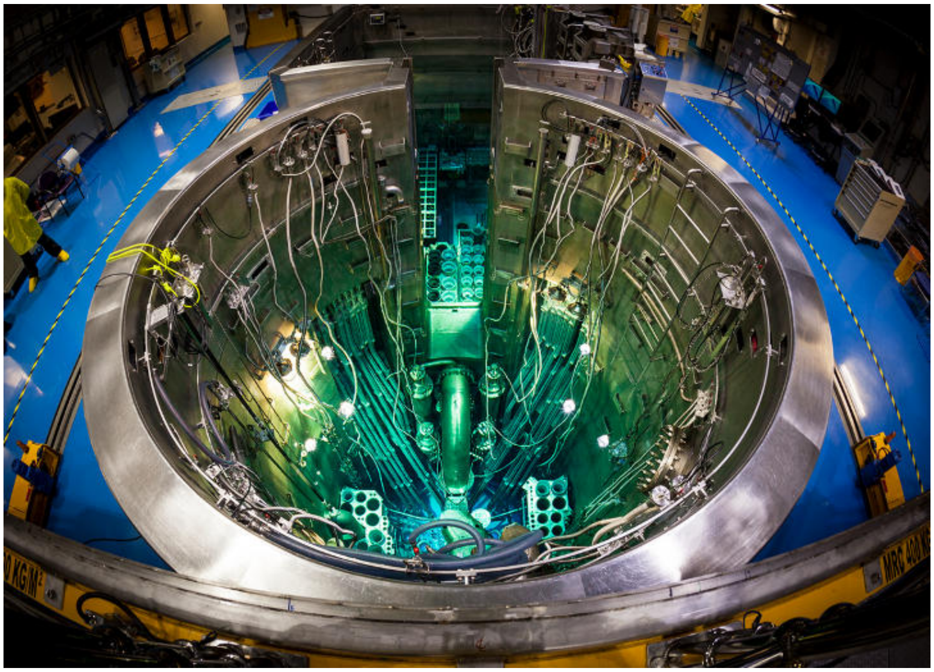

Figure 6: OPAL RPO (foreground) and channel connecting to the SPO (background)

In 2017 and 2018, prior to the commencement of any spent fuel loading operations, AREVA will provide ANSTO personnel with training in the use of TN-MTRs. AREVA will also provide technical assistance during actual loading operations.

It is planned to bring the TN-MTR casks into the OPAL reactor hall during one of the regularly scheduled reactor maintenance shut-downs. The TN-MTRs will enter the reactor hall via a hatch in the reactor hall floor. ANSTO's reactor hall crane, which is rated for lifting nuclear materials, will be used for the operation.

Each TN-MTR will be prepared next to the SPO and then, one at a time, lowered to a position at the bottom of the SPO near the fuel assembly storage rack. One at a time, spent fuel assemblies will be transferred directly from the storage rack into the TN-MTR. Once loaded, TN-MTR will be lifted from the SPO and then thoroughly drained, dried and leak tested in preparation for shipment to France.

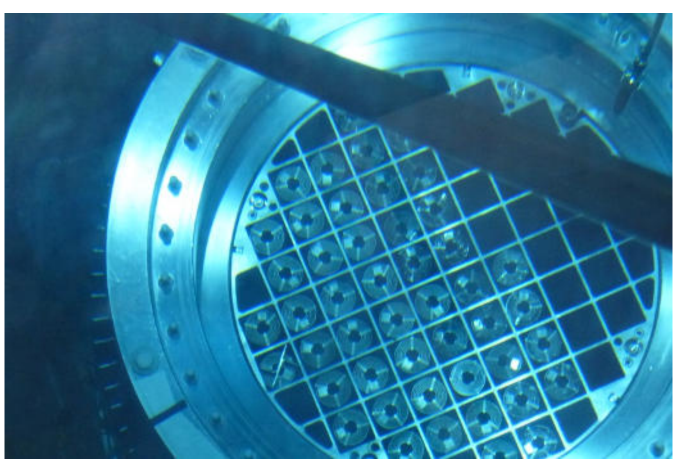

Figure 7: TN-MTR in-pool loading at BR2 reactor, Belgium © SCK•CEN

The loaded casks will be transferred out of the reactor hall through the same hatch used for entry. ANSTO will utilise an experienced logistics supplier and work with local and federal government agencies to ensure the safe and secure transportation of spent fuel to a port on the east coast of Australia where the casks will be loaded onto a ship for transportation to France.

7. Return of Intermediate Level Waste (ILW)

As mentioned previously, it is expected there will be two returns of ILW resulting from the reprocessing of all OPAL spent fuel. ANSTO and AREVA have previously worked together on the return of ILW resulting from the reprocessing of HIFAR spent fuel. Figure 7 below shows a schematic for the 2015 ILW return. The CSD-U vitrified waste was set in stainless steel canisters, which were then packed into an AREVA TN-81 type cask. The TN-81 is an attractive cask design because it is dual purpose; it can be used for both transporation and long term storage with minimal maintenance.

The TN-81 arrived in Australia in December 2015. Australia has not yet established a national radioactive waste management facility and so the TN-81 was transferred to a dedicated storage building at ANSTO for interim storage. The return of the ILW has been an excellent exercise in demonstrating to the Australian public that the waste arising from the long term operation of a research reactor can be managed in a safe, secure and sustainable manner. ANSTO has also selected the TN-81 cask for the return of the ILW resulting from the reprocessing of HIFAR spent fuel in the UK. This ILW shipment is scheduled for approximately 2021.

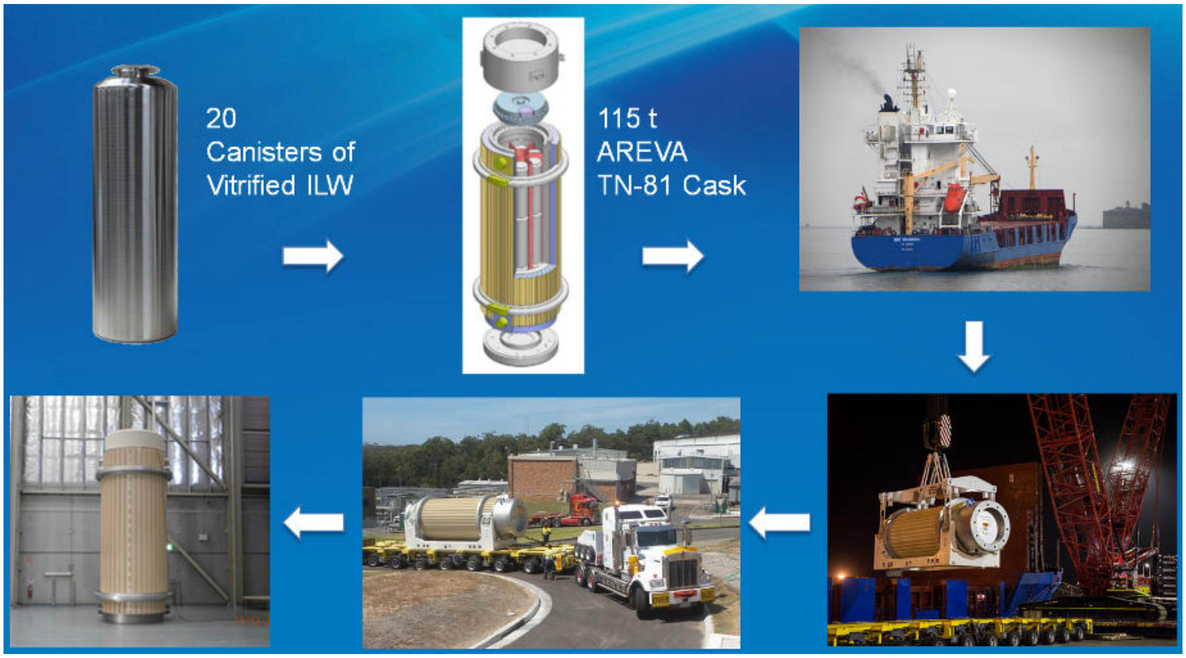

Figure 8: 2015 ILW return for reprocessed HIFAR spent fuel

A similar approach is planned for the eventual return of ILW resulting from the reprocessing of OPAL spent fuel. However, by the time the OPAL ILW is returned it is expected that Australia will have an operational national radioactive waste management facility for the long term storage of all ILW produced at ANSTO.

The Australian Government is currently in the final stages of selecting the site for the National Radioactive Waste Management Facility. Additional information is available at http://www.radioactivewaste.gov.au/. This facility is distinct and separate from the international spent fuel and ILW storage facility, which was considered as part of the 2015-16 South Australian Government independent investigation into the potential for increasing its participation in the nuclear fuel cycle.

8. Conclusion

ANSTO has more than 50 years of experience in the management of research reactor spent fuel. ANSTO has used this experience, together with AREVA's expertise in spent fuel transportation and reprocessing, to establish an effective and world leading plan for the management of OPAL spent fuel.

The ANSTO-AREVA plan will enable the OPAL reactor to continue operating with a very high utilisation and maintain its reputation as one of the best research reactors in the world. ANSTO and AREVA are now working closely together for the first shipment of OPAL spent fuel, which is scheduled for mid-2018.