# The ANSTO / Australian Process and Application to Existing Spent Fuels and New Reactors

**Lubi Dimitrovski**

Technical Meeting on Operating Experience and Lessons Learned on Managing Non-Standard Legacy Power and Research Reactor Spent Fuels
IAEA, Vienna, 18-21 February 2021

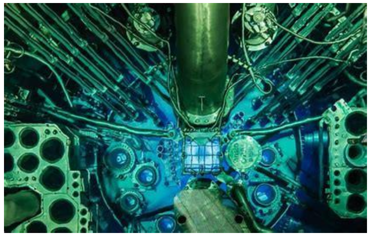
# Overview

- Background
- Operational Experience in managing RR Spent Fuel
- Lessons learned

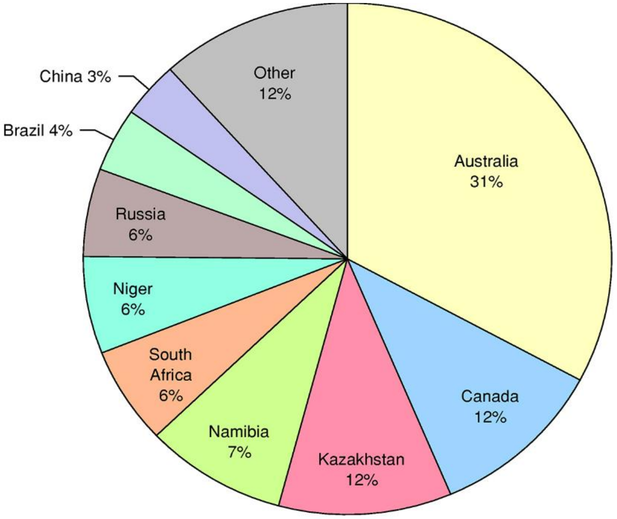
# Nuclear in Australia

- No nuclear power industry.
- Uranium mining – ONLY two mines currently operating, Olympic Dam and Beverley Four Mile. Both are in South Australia.
- The world's largest uranium reserves(30%), 4th largest producer of yellowcake (U3O8)
- The Australian Nuclear Science and Technology Organisation (ANSTO) operates Australia's only reactor - 20MW research reactor (OPAL)
- Nuclear power and Australia's role in the nuclear fuel cycle is still being debated.
- AUKUS - ttrilateral security partnership (Australia, UK & US) for nuclear powered submarines was signed in Oct 2024.

Olympic Dam



OPAL Research Reactor



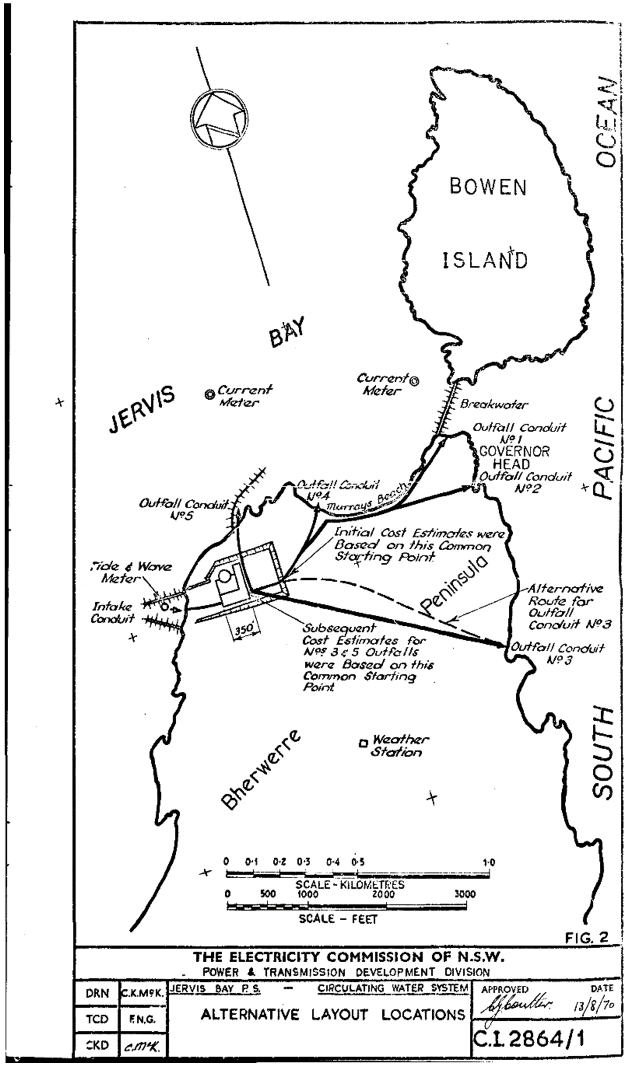

World Uranium Resources

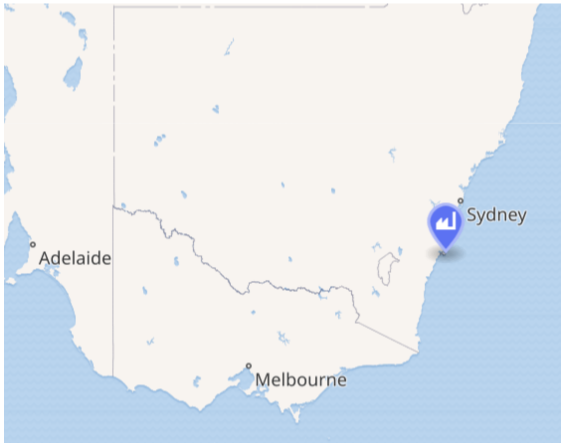
# Nuclear Power Strongly Considered in 1960's

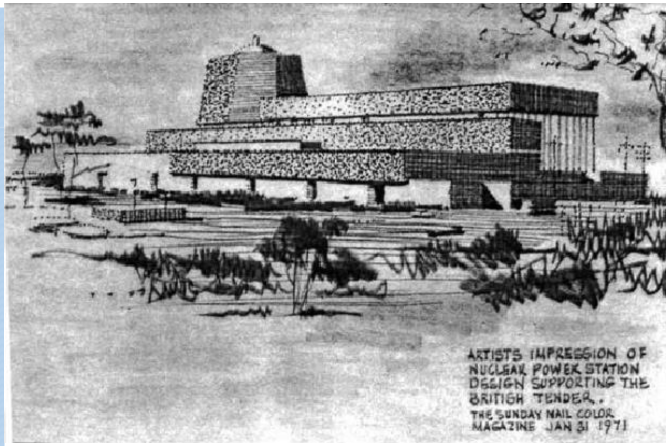
500 MWe NPP proposed in 1969

1970 acceptance of a tender to supply a 600 MWe Steam generating heavy water reactor (SGHWR), from the British organisation, *The Nuclear Power Group*.

Government Change in 1971 and decision to not proceed due to high cost, discovery of abundant fossil fuels (coal and oil) and a growing anti-nuclear lobby



# ANSTO

| | |
|---|---|
| Formed in 1953 as the AAEC<br>1958 HIFAR RR critical<br>1987 ANSTO established | 2 x Research Reactors Closed<br>- 10 MW HIFAR (1958 - 2007)<br>- 100 KW Moata (1961-1995) |
| 20 MW OPAL Reactor 2006 ⟶ | Circa 1300 employees |
| 25km from Sydney CBD | Safe management of spent fuel for 67 years |

# Australian/ANSTO Research Reactors

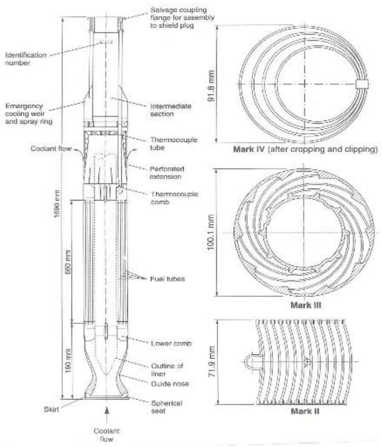
**10 MW HIFAR** (1958 - 2007)
High Flux Materials Test Reactor
DIDO Class (UK), Heavy Water Moderated, contained i
n an aluminium tank , surrounded by a graphite reflector
Neutron diffraction, NTD Silicon, medical isotopes
Undergoing decommissioning

**100 kW MOATA** (1961 - 1995)
HEU Fuel (UAl), 92% enriched
Argonaut class reactor (US design)
Used for Research and training

.

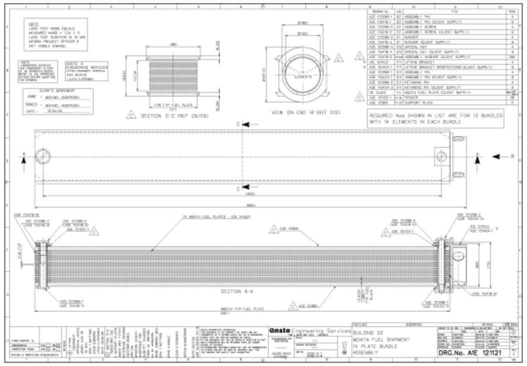
**20 MW OPAL** (2006 ⟶)
LEU Fuel ($U_3Si_2$) , 19.75% enriched
Heavy water moderated, open pool reactor
Medical isotopes, NTD Silicon and Neutron
Beam instrument research

# ANSTO Research Reactor Fuels Types




## HIFAR

60%-90% HEU fuel assemblies - uranium-aluminium clad alloy in an aluminium matrix.
Converted to <20% LEU (U3Si2) fuel in mid-2006 until its closure in January 2007
Average burnup per FE of 54.4 MWd
**(Spent Fuel - Combination of WET & DRY STORAGE at Reactor site)**



## MOATA

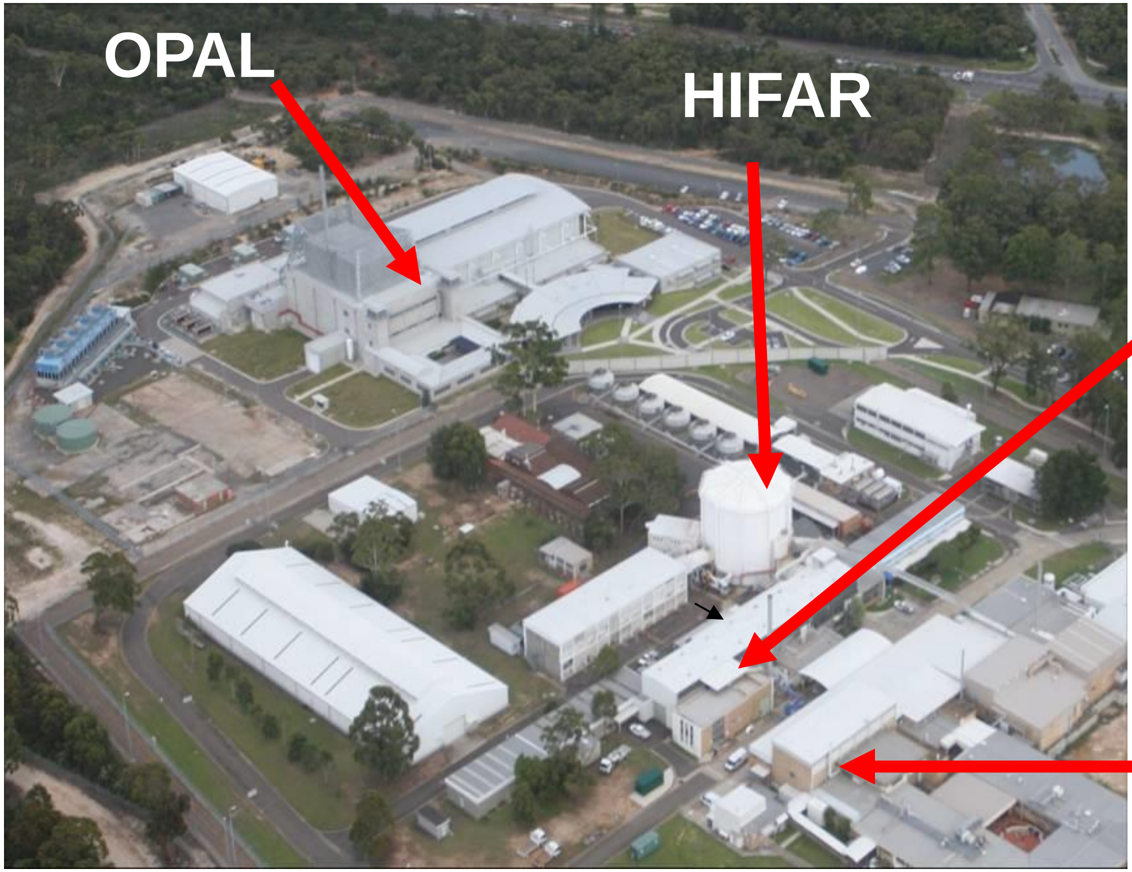
60% - 90% HEU fuel assemblies , 12 aluminium clad fuel plates, 22-23 g of U-235 in an aluminium/uranium alloy
**(Spent Fuel - DRY STORAGE at Reactor site)**

## OPAL

19.75% LEU (U3Si2) fuel, uranium-silicide dispersed in aluminium and clad in aluminium. 1045mm x 80mm x 80mm, 21 flat plates, Active fuel 615mm x 65mm
**(Spent Fuel - WET STORAGE at Reactor site)**

# At Reactor Site - Spent Fuel Storage

# Spent Fuel Wet Storage - ANSTO

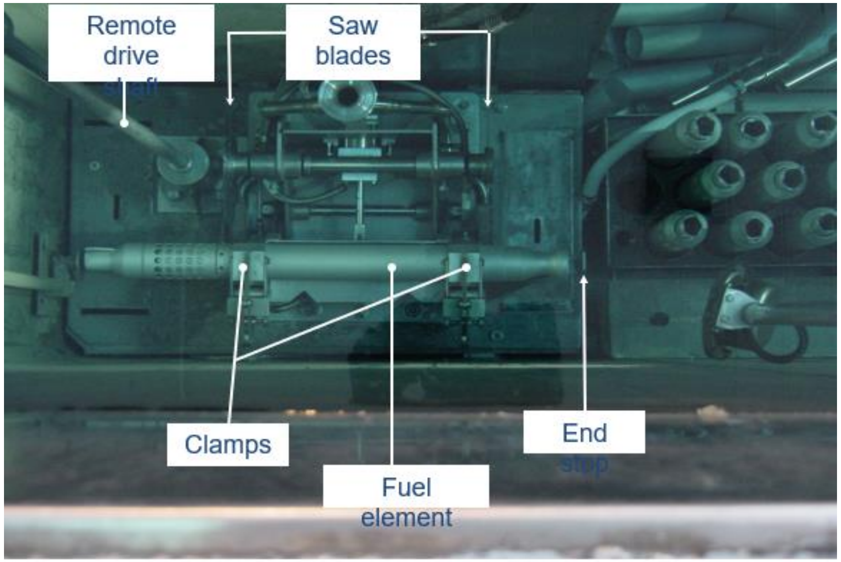




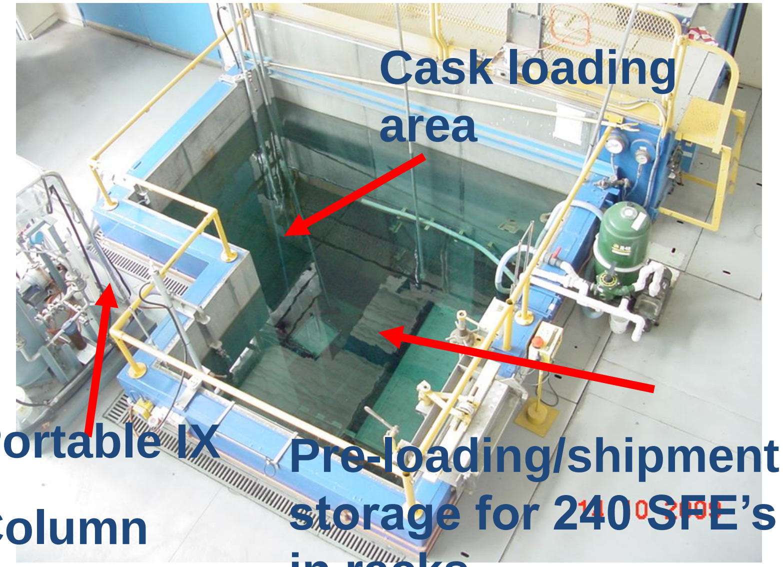

**Two wet storage ponds in different locations**

# Legacy Spent Fuel - Wet Storage/Loading Ponds


Cropping Pond



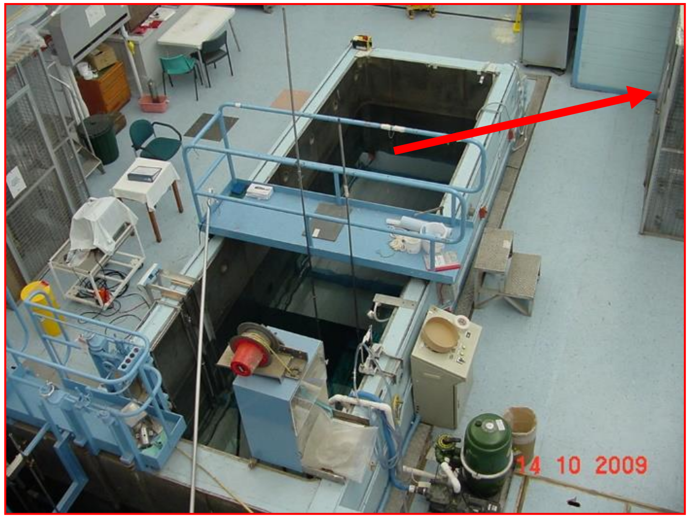

Cropping Pond Saw



Cask loading area

Portable IX Column

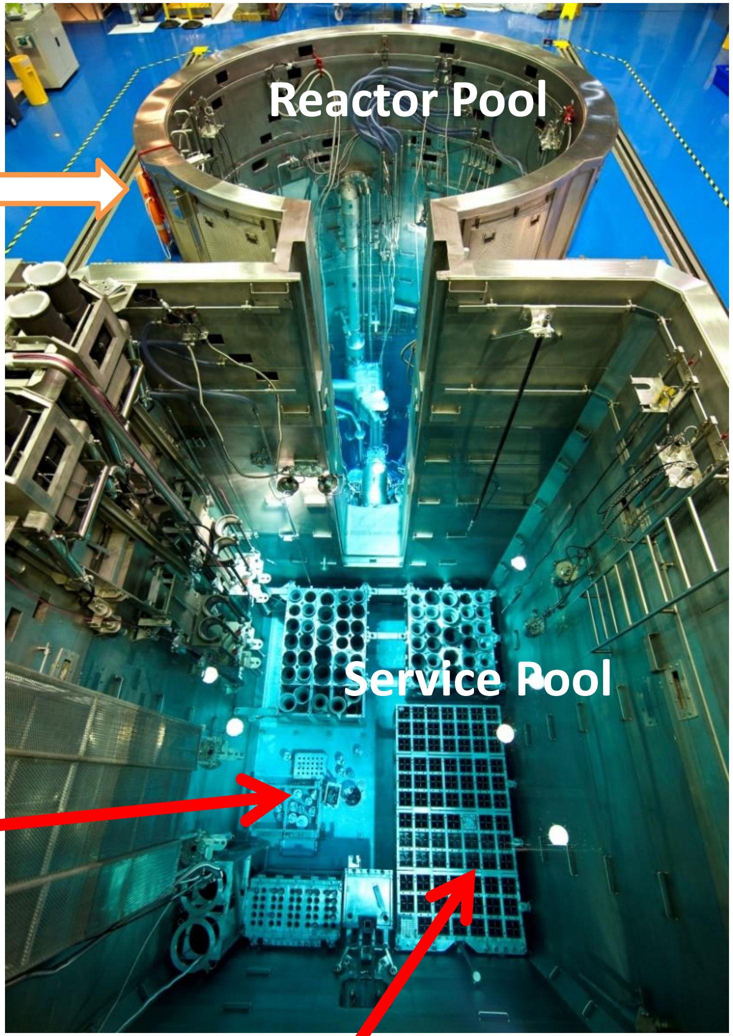
Pre-loading/shipment storage for 240 SFE's in racks




Storage Pond – 390 SFE's in racks

# Wet Storage - OPAL Research Reactor

OPAL Reactor  Control Room




SF In-pool Cask loading

27-30 Spent Fuel Elements per year

Spent Fuel Storage Rack
336 SFE capacity

# ANSTO - Legacy RR Spent Fuel Dry Storage

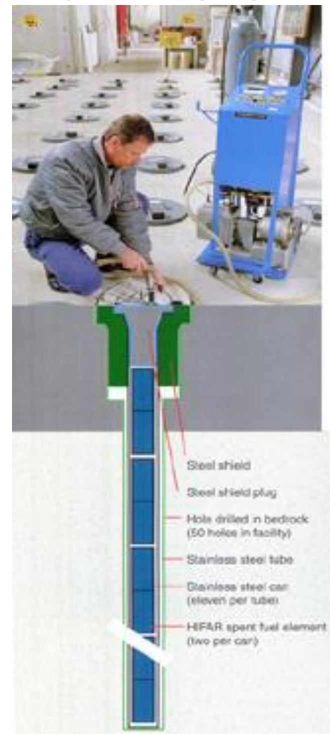
HIFAR

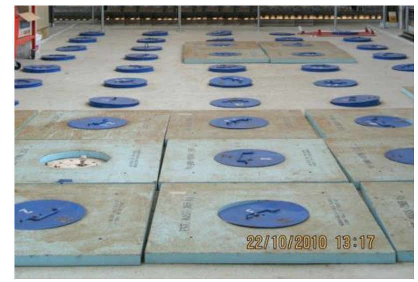
Dounreay Multi Storage & Transport Flasks

Wet storage

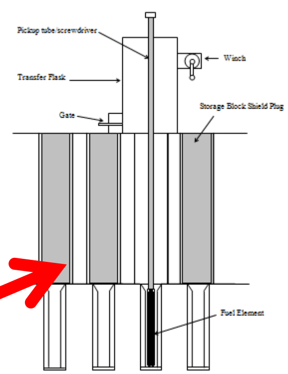
Spent Fuel Transfer Flask

Dry Storage (1100 SFE's)



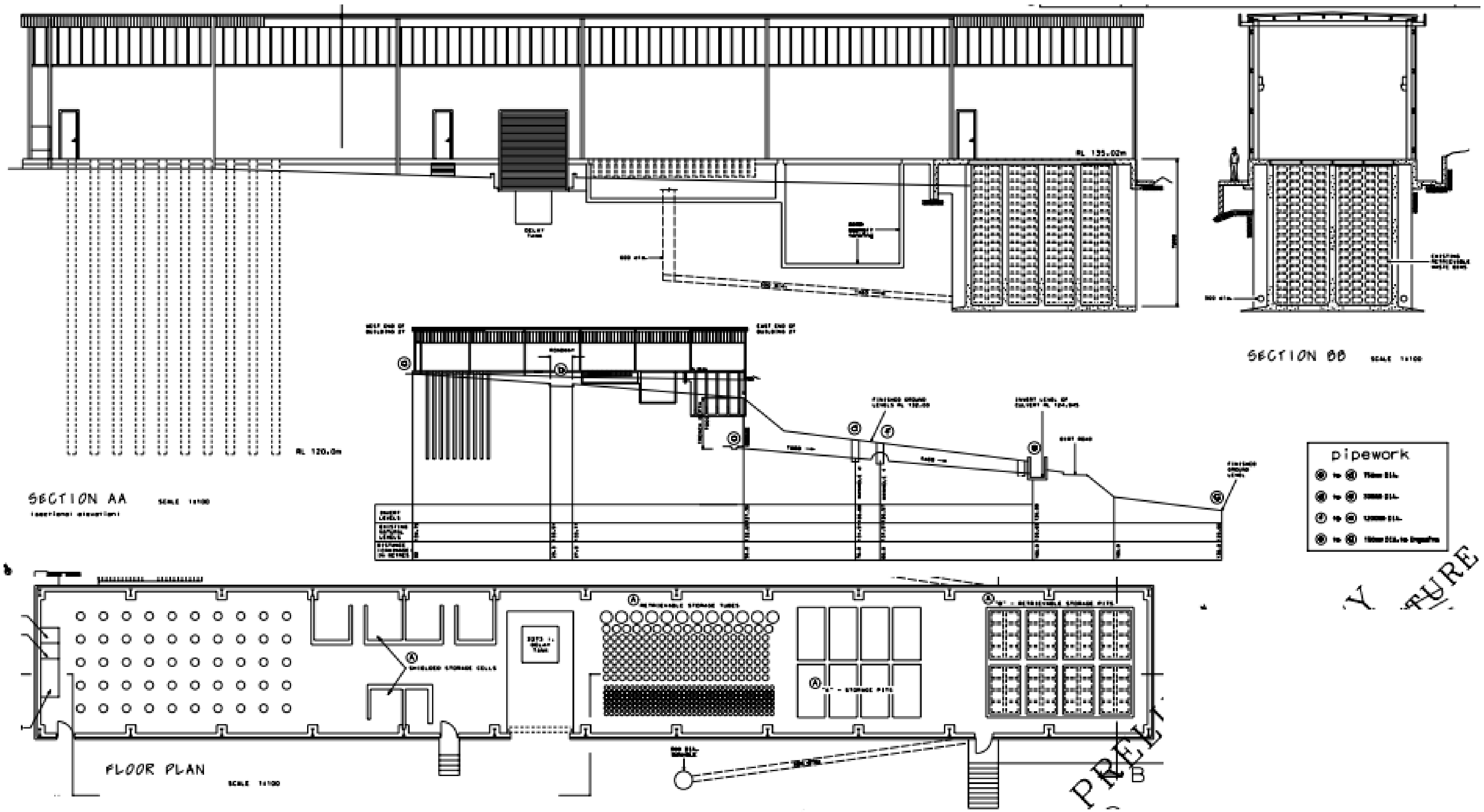




MOATA




MOATA SF Dry Storage Block

# Spent Fuel Dry Storage




1960's

1980 -2012

2012 →

**50 Years of Dry Storage**;

- 2200 SFE's
- 19 SFE's with minor corrosion

# ANSTO Spent Fuel Management

## 1958 -1997 HIFAR RR

- Spent fuel accumulated on site using a combination of dry and wet storage facilities
- Ad-hoc shipments to the UK ( Dounreay reprocessing 1963 & 1996).
- Australia government considering reprocessing in Australia 1960's to 1997
- Nov 1993
  - 1086 SFEs in B27 Main Storage Facility (98.7% full)
  - 175 SFE's in seven Dounreay Transport Casks (routinely sampled and monitored)
  - 114 SFEs in an ANSTO LHRL-120 cask awaiting transport to the US (cask capacity 120 SFE's
  - 237 SFEs in underwater storage in the B23 Pond (Capacity 390 SFEs.)
  - All requiring periodic IAEA safeguards inspection for verification purposes

## 1997 HIFAR and OPAL RR

- Government decision:
  - To construct a replacement research reactor at Lucas Heights (OPAL) in 1997 (OPAL Reactor critical Aug 2006).
  - Not pursue establishment of a reprocessing facility at Lucas Heights or anywhere else in Australia.
  - Funding ($88M) was set aside to remove spent fuel from ANSTO and meet the costs of reprocessing offshore
- UK government decision to stop all commercial reprocessing in 1998 (Dounreay)
- Uncertainty of US Takeback Program for Foreign RR Spent Fuel (mainly focused on HEU)
- HIFAR SF shipped 1288 SFEs to La Hague France between 1999-2004 fot reprocessing the HEU UAl SF
- In 2015 signed a contract with AREVA (now ORANO) for maritime transport and processing of the OPAL U3Si2 SF Reactor following the La Hague establishing capacity to reprocess silicide fuel.

# ANSTO Spent Fuel Management

| | | |
|---|---|---|
| 1963 | **Dounreay** | 150 FA |
| 1996 | **Dounreay** | 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 |
| Dec 2018 | **ORANO** | 256 FA |
| Mar 2021 | **UK** | ILW Return |

2281 HIFAR SF assemblies in 9 shipments

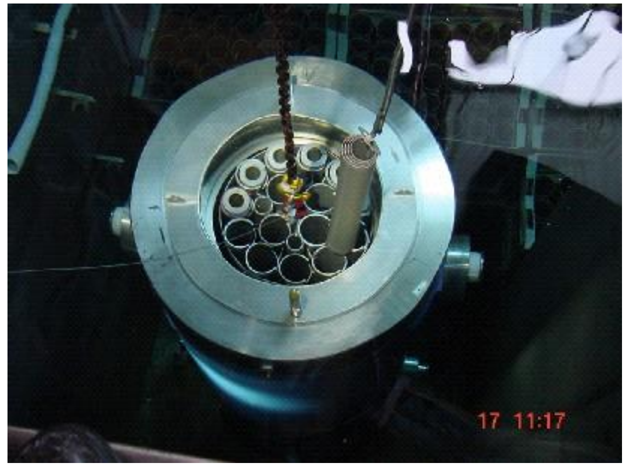
ILW from reprocessing of 1288 HIFAR SF assemblies returned from France

Return of vitrified waste residues (ILW) France

1st OPAL SF Shipment to France (Orano)

Return of vitrified waste residues (ILW) UK

# At Pool Cask Loading of Legacy Spent Fuel



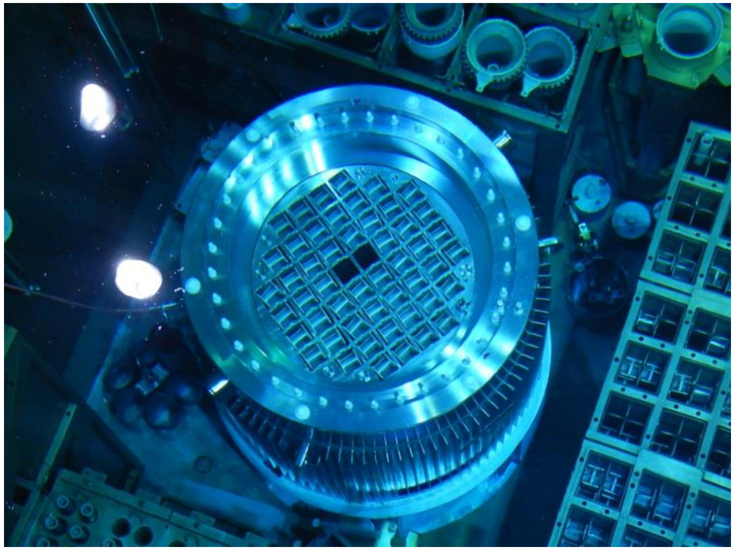


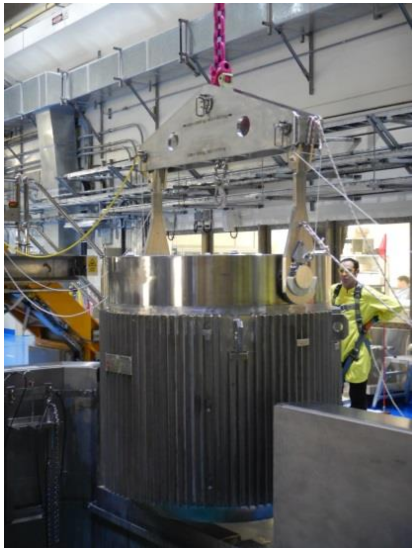
# Mixed Loading - At Pool and External (Dry) Loading of Legacy SF

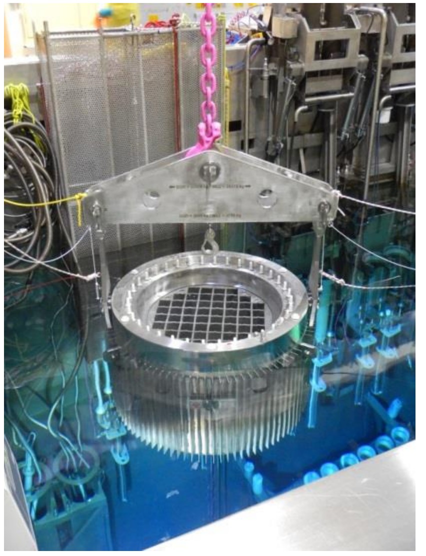




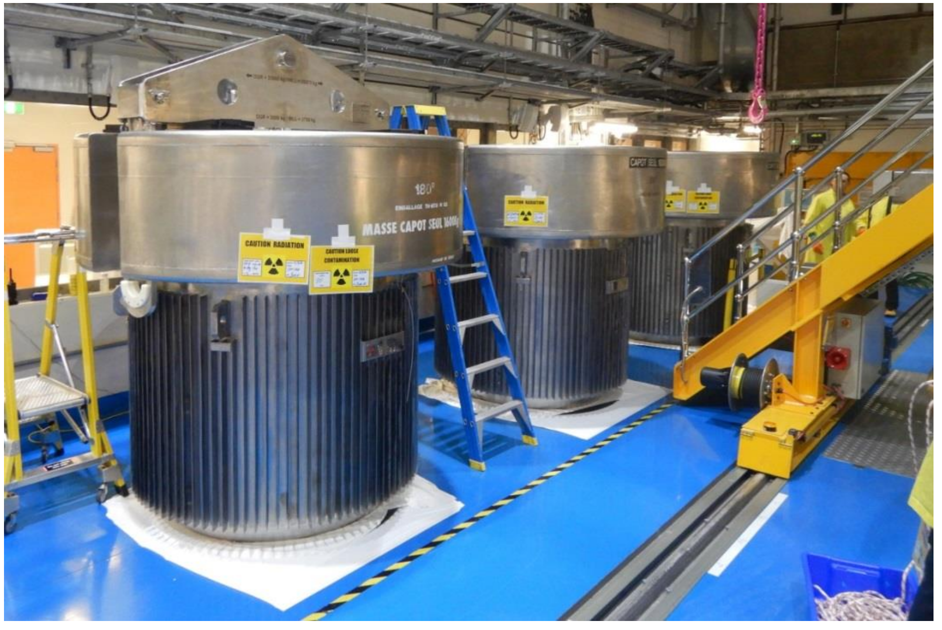
# 1st Opal Spent Fuel Shipment (2018)







Direct Loading of SF into TN-MTR Transportation Cask in OPAL Service Pool with Reactor at Power
4 x TN-MTR casks used to ship 236 SFE’s
3 x Casks leased
1 x Cask ANSTO owned



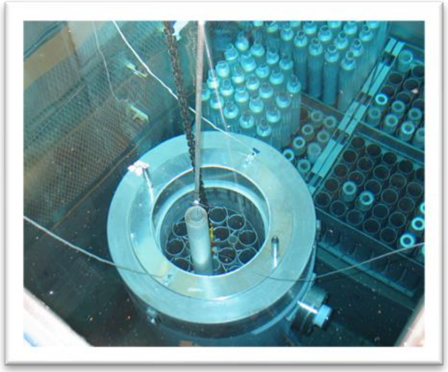

**First SF shipment to France – completed July 2018**

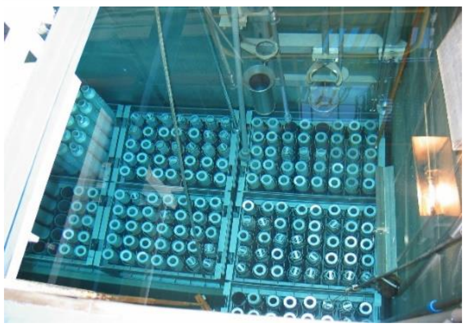
**Second shipment planned for 2025**

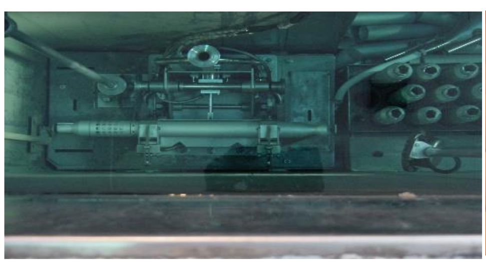
# Pond Water Chemistry Monitoring Frequency

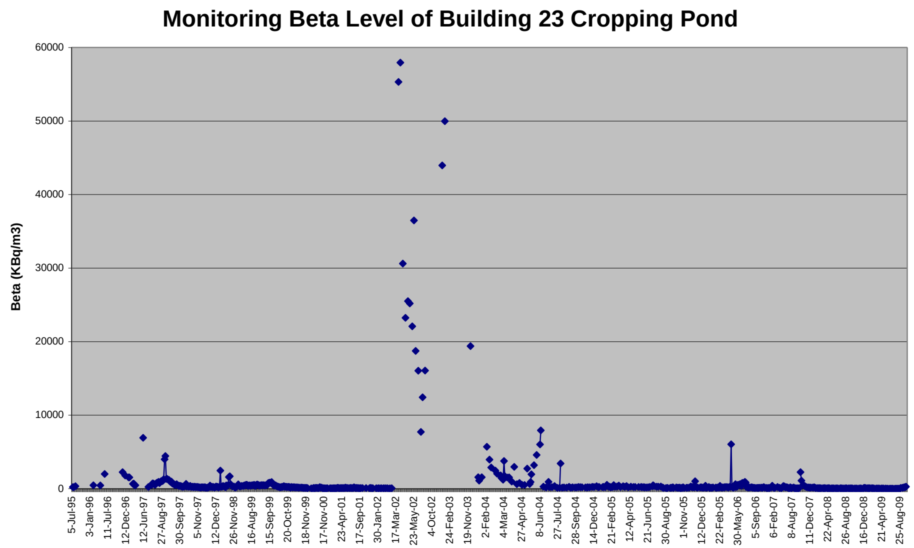
| Parameter | Normal Range | Notification Level | Minimum Frequency |
|---|---|---|---|
| pH | *5-8* | *<5, >8* | *weekly* |
| Conductivity, μS/cm | *1-10* | *>20* | *weekly* |
| Gross α, Bq/mL | *<0.02* | *>0.02* | *weekly* |
| Gross β, Bq/mL | *<0.50* | *>1.0* | *weekly* |

# Wet Storage of Legacy RR Spent Fuel





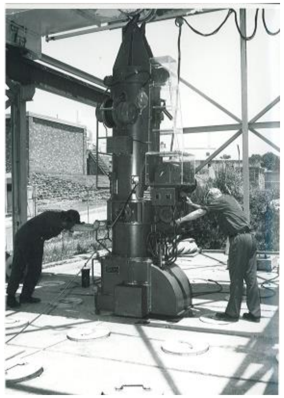


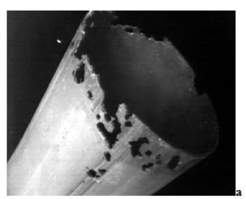


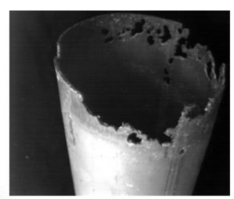

## Legacy Spent Fuel

- 40 years safe wet storage
- Maintenance of pond water chemistry
- NO fuel degradation in wet storage
- One incident of note in 2002 due to incorrect cropping procedure
  - pond water chemistry recovered by the pond IX system
  - cropped element canned in overpack

# Dry Storage of Legacy Spent Fuel







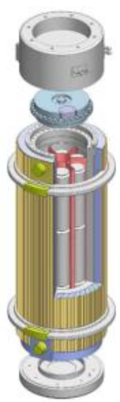
- Dry storage of legacy SF between 1958 -2008
- Sparodic monitoring program prior to1990
- Improved post 1990 with better shielding plug sealing and humidity control
- Minor pitting corrosion to 19 out of 2200 SFE’s in dry storage (<1%)
- Pitting occurred at the tube ends and along the electron beam welds that join the three curved plates into a cylinder
- All 19 compromised SFE’s were inspected and cleaned up (in a Hot Cell) and underwent comprehensive inspection and preparation in order to comply with the strict acceptance criteria for the Savannah River Site (US).

# Why Reprocess Spent Fuel?

- The Australian Government  has remained committed to reprocessing all current and future spent fuel inventory.
- U and Pu extracted from spent HIFAR fuel used to fabricate Mixed Oxide Fuel (MOX) and Enriched Reprocessed Uranium (ERU) to fuel European commercial power reactors for peaceful use.
- Opportunity to reprocess Spent Fuel at La Hague (France) and access resulting fission product as ILW category vitrified (glass) in universal CDS-U canisters
- Vitrified ILW is stable, low volume and amenable for long term storage before final disposal.

***1288 HIFAR Spent Fuel Elements were  shipped  to La Hague for reprocessing  (28 out of 49 Years of HIFAR RR Operation) for 20 ILW x CSD-U Vitrified Glass Canisters able to be stored in a single TN81 dual transport storage Flask for > 40 years (less than < 2 KW/m3 to meet the ILW definition and flask surface contact radiation dose of <5μSv/hr***

20 CSD-U Canisters placed in 4 stainless steel baskets

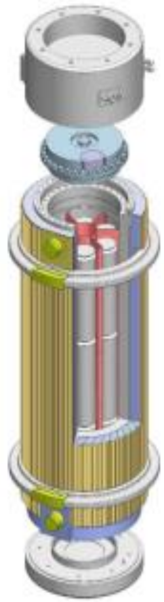


TN81Cask
7.215 m L
2.750 m D
115 T W

# ILW Return (France 2015 and UK 2022)

**CSD-U Canisters (ILW Category) amenable for direct borehole disposal**

Vitrified CDS-U Glass Waste Canisters



115 tonne TN-81 Cask

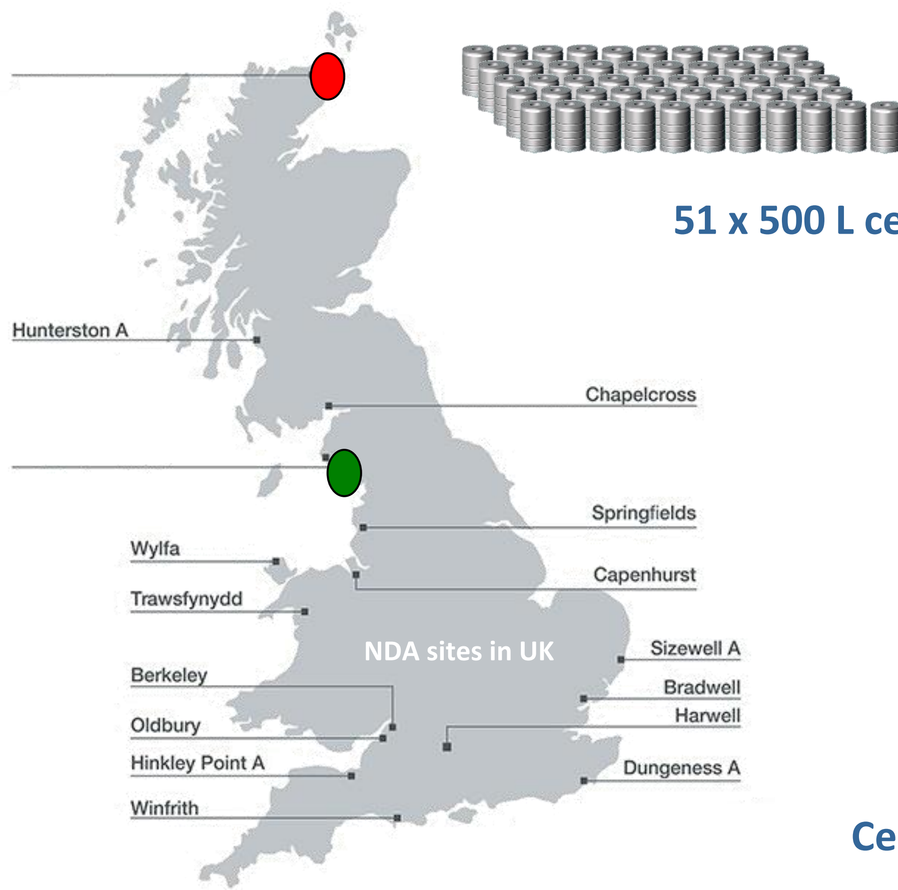

**20 Canisters from UK**

**4 Canisters from UK**

# UK Waste: Activity Swap

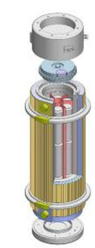
Dounreay

Sellafield




51 x 500 L cement filled drums

4 glass waste canisters



Certified Container

Dec 2015 ILW from France

Legacy HIFAR/MOATA RR Spent Fuel

2281 SFE's generated

- 1288 reprocessed at La Hague
- 264 reprocessed at Dounreay
- 729 to US takeback program

March 2022 ILW from UK

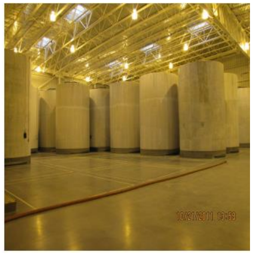
# AUKUS Nuclear Powered Submarines Trilateral Agreement - HLW Challenge

- AUKUS – Trilateral agreement signed between Australia, the UK and the US in 2024.
  1. US subs to be deployed in Australian ports
  2. Procurement of US submarines
  3. New UK/Australian collaborative design constructed in SA in 2040s and beyond
  4. $368 Billion budget?
- **AUSTRALIA has no Nuclear Power Program**
- No disposal sites for LLW/ILW in over 40 years with 3 failed attempts
- Despite bi-partisan support governments have “kicked the bucket down the road” 3 times
- Australian Defence minister announced Australia would dispose of the submarine Spent Fuel/HLW domestically with the first submarine spent fuel core commencing in the 2050s?

# AUKUS - HLW Management

## US

- Upon decommissioning, spent fuel is removed and conditioned for dry storage
- All Naval spent fuel is shipped to the Idaho Naval Reactors Facility by rail and since 2008, the spent fuel has been placed in Canisters for dry storage.



**IDAHO – SF**


**Navy will be responsible for the shipment to a future the repository** .

## UK

- The UK's nuclear-powered submarines are currently defueled and refuelled at the Devonport Royal Dockyard (Plymouth) at least once during their service life.
- As of 2011 the UK had ten defueled decommissioned submarines stored afloat at Devonport, four of which have been defueled and the remaining six are awaiting the completion of new defueling facilities.
- A further seven defueled submarines are currently stored afloat at the Rosyth Royal Dockyard on the Firth of Forth in Scotland

## FRANCE

- Nuclear submarines are de-fuelled at Cherbourg and the SF is sent to La Hague for initial cooling period before being reprocessed.

# ANSTO Synroc®

A safe, secure and sustainable radioactive waste solution

ANSTO's Synroc Technology is a highly flexible waste treatment process that employs hot-isostatic pressing (HIP) consolidation.

The technology allows for the production of a range of wasteform classes: ceramic, glass, and advanced composite wasteforms such as cermets and glass-ceramics.

# Why Use Synroc Technology?

## Inspired by nature

- Based on naturally-occurring, highly-durable mineral phases
- Locked up U, Th over geological timeframes

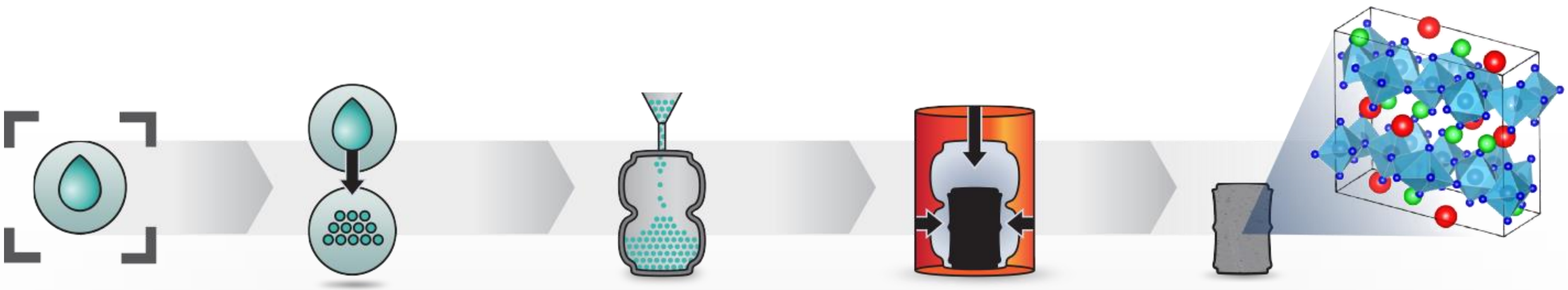
## Substantial benefits

- High durability
- Low disposal volumes
- Suited for problematic wastes
- Flexible modular technology

### ANSTO

- First of a kind Synroc Plant
- Mo-99 production waste

# ANSTO Synroc® Technology



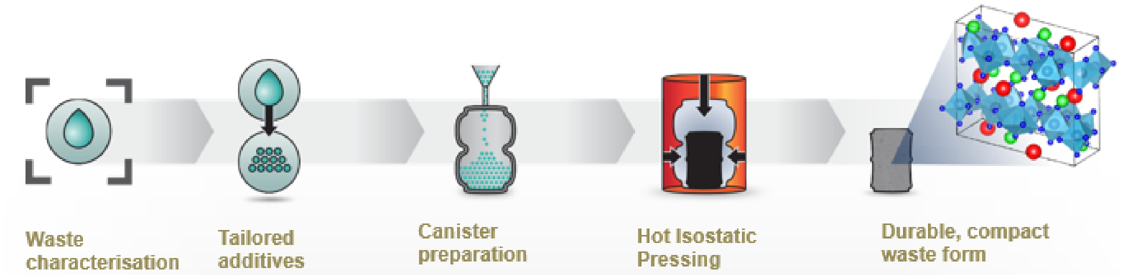

Decades of international study underpin Synroc wasteforms

Complementary to existing technologies such as vitrification

Ability to accommodate a broad range of challenging radioactive wastes

ANSTO

# ANSTO Synroc® Technology

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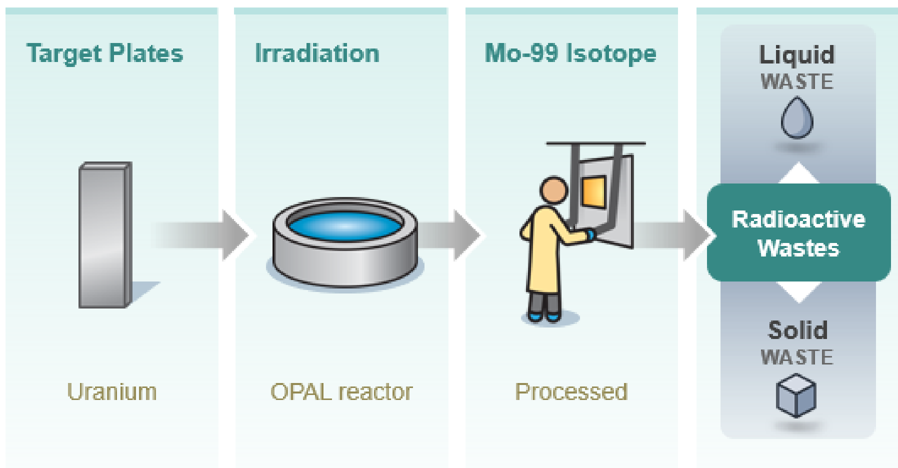
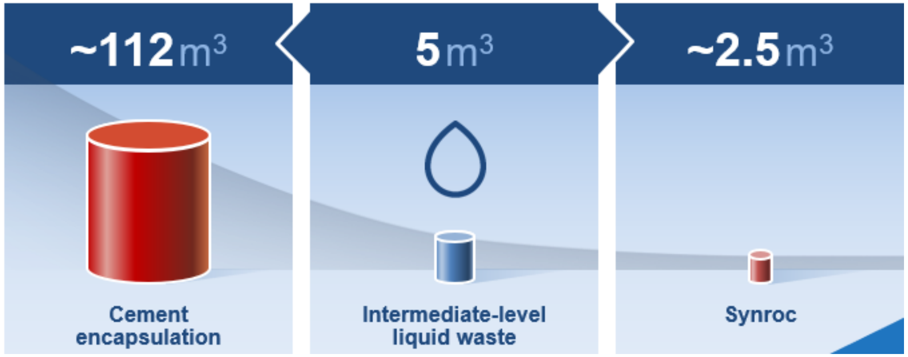
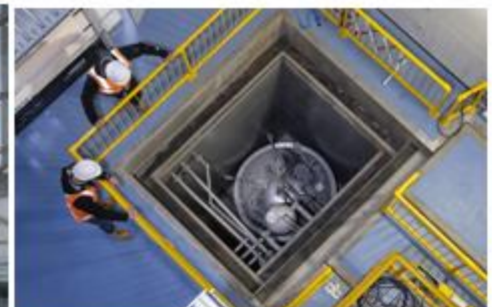
# Mo-99 production at ANSTO




## ANSTO Synroc® advantage for Mo-99




# Facility construction



# Synroc Potential

Exotic fuel

Future MSR Fuels

Can be applied to
liquid or solid wastes

**Synroc process** →

# Small Modular Reactors

The link below is from a private group of engineers in Australia providing important information about small modular reactors to the general community:

- https://small-modular-reactors.org/

They highlight the advantages of SMRs

1. **Improved safety**: SMRs are designed with inherent safety features, such as passive cooling systems that do not rely on external power sources, reducing the risk of accidents.
2. **Scalability**: The modular design of SMRs allows for the addition of more reactors as needed, providing a flexible and scalable solution for power generation.
3. **Lower capital costs**: The smaller size and modular nature of SMRs reduce construction and licensing costs, making them more financially viable for a wider range of applications.
4. **Reduced nuclear waste**: Some SMR designs can utilize used nuclear fuel, helping to address the issue of nuclear waste disposal.
5. **Fuel flexibility**: The ability of SMRs to use a variety of fuel sources, including uranium, thorium, and used nuclear fuel, provides more fuel options and supply chain diversity.

# Conclusion & Lessons Learned (1)

- Safe management and storage of legacy and new spent fuel at ANSTO for 67 years.
- Whilst the legacy and current fuel used by the ANSTO RR's has been standard UAl and U3Si2 the safe management over long periods of time brings challenges that require constant and vigorous oversite.
- The Spent Fuel inventory from operation of 2 x former research reactors fully dispositioned (life cycle management).
- Wet and Dry Storage facilities are now empty and currently used for interim storage of specific high dose rate nuclear waste awaiting processing/conditioning.
- The former SF Dry Storage Facility has been refurbished and re-purposed to store uranium filter cups from Mo99 Production.
- Of the legacy 2281 SFE's generated to 2007 -only 19 were considered partially "compromised". These SFE's were inspected, stabilised and canned in specific overpack to meet the acceptance criteria at end receiver (Savanah River Site) as part of the US RR SF Takeback program.

# Conclusion & Lessons Learned (2)

- Negotiated return of reprocessed waste returned as ILW category vitrified canisters (CSD-U) (low volume, easily stored and amenable for final disposal .e.g. medium depth borehole disposal ~ 2km depth).
- Regulatory and public confidence gained in managing the spent fuel.
  - 9 x legacy SF shipments to US, UK and France
  - 2 x shipments of reprocessed fission product waste
  - Ongoing shipments of OPAL SF for reprocessing (2018) and one planned this year.
- Worked closely with government to ensure strategies are supported with timely funding.
- Availability of trained/competent staff to work SF management program - 7 shipments in 11 years.
- Supporting site R & D programs for long term management of SF.
- SF Shipment panning and logistics:
  - Numerous organisations involved in shipping SF half-way around the world.
  - Availability of certified SF transport casks and specific International Nuclear Freight INF) cargo ships.
- National disposal program for LLW and interim storage of ILW remains a challenge (socially and politically) with 3 x failure attempts by Government over 30 years to find a disposal site.
- **The AUKUS and Nuclear Submarines agreement brings SF/High Level Waste management on the table.**

# Thank you