Decommissioning of Windscale Advanced Gas-Cooled Reactor (WAGR)

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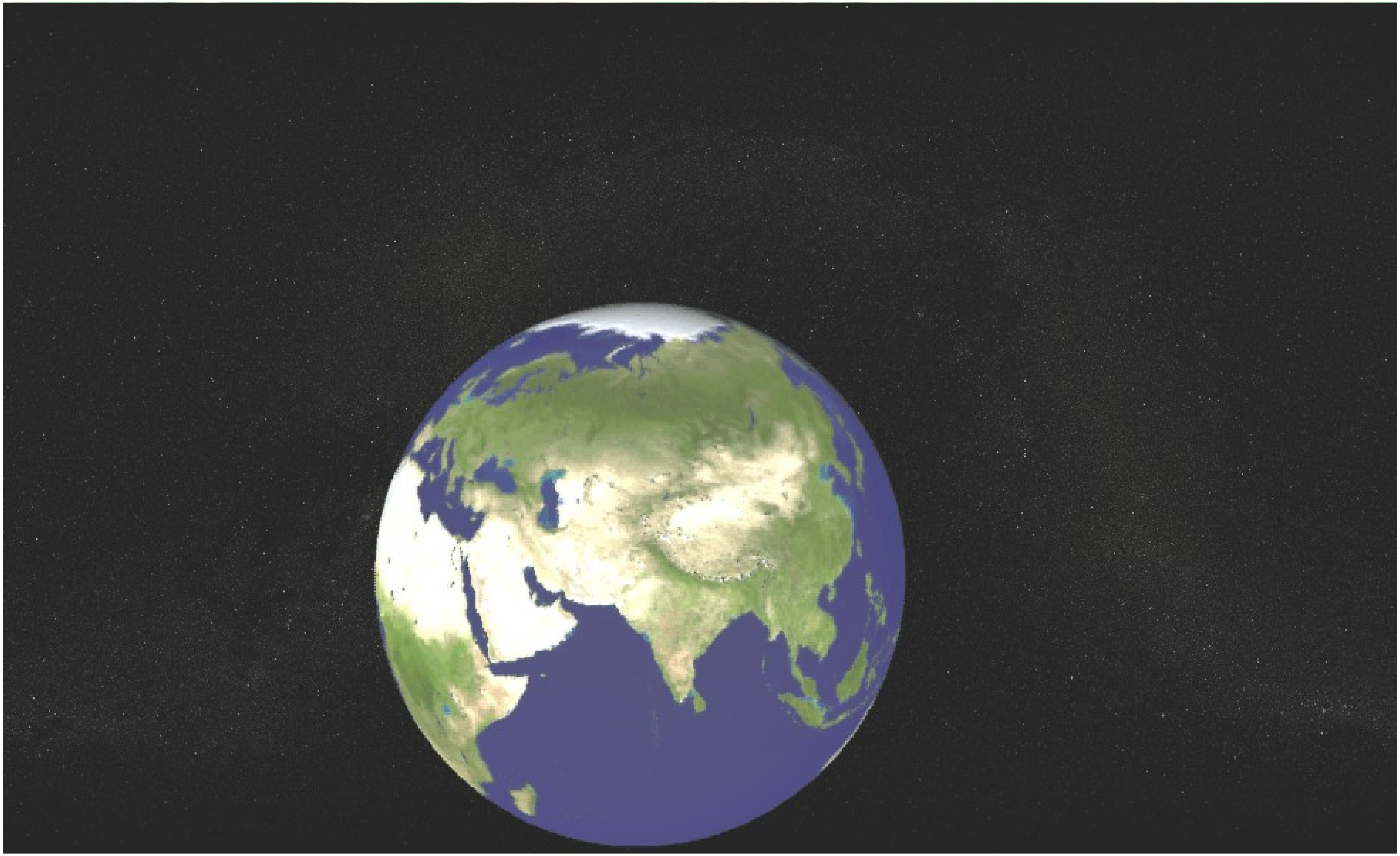
Introduction

- UK policy for nuclear power plant decommissioning is long-term safe-storage of reactor facilities
- WAGR Project is being used to demonstrate that such a plant can be fully decommissioned
- Project funded by the UK Government
- Windscale Licensee UKAEA
- During early and mid 1990's facility modified and construction of Reactor Dismantling Machine and Waste Route
- 1999 contract let for the dismantling of the reactor to Magnox Electric – fixed price
- Scope included engineering and design, safety submission, provision of equipment and operations

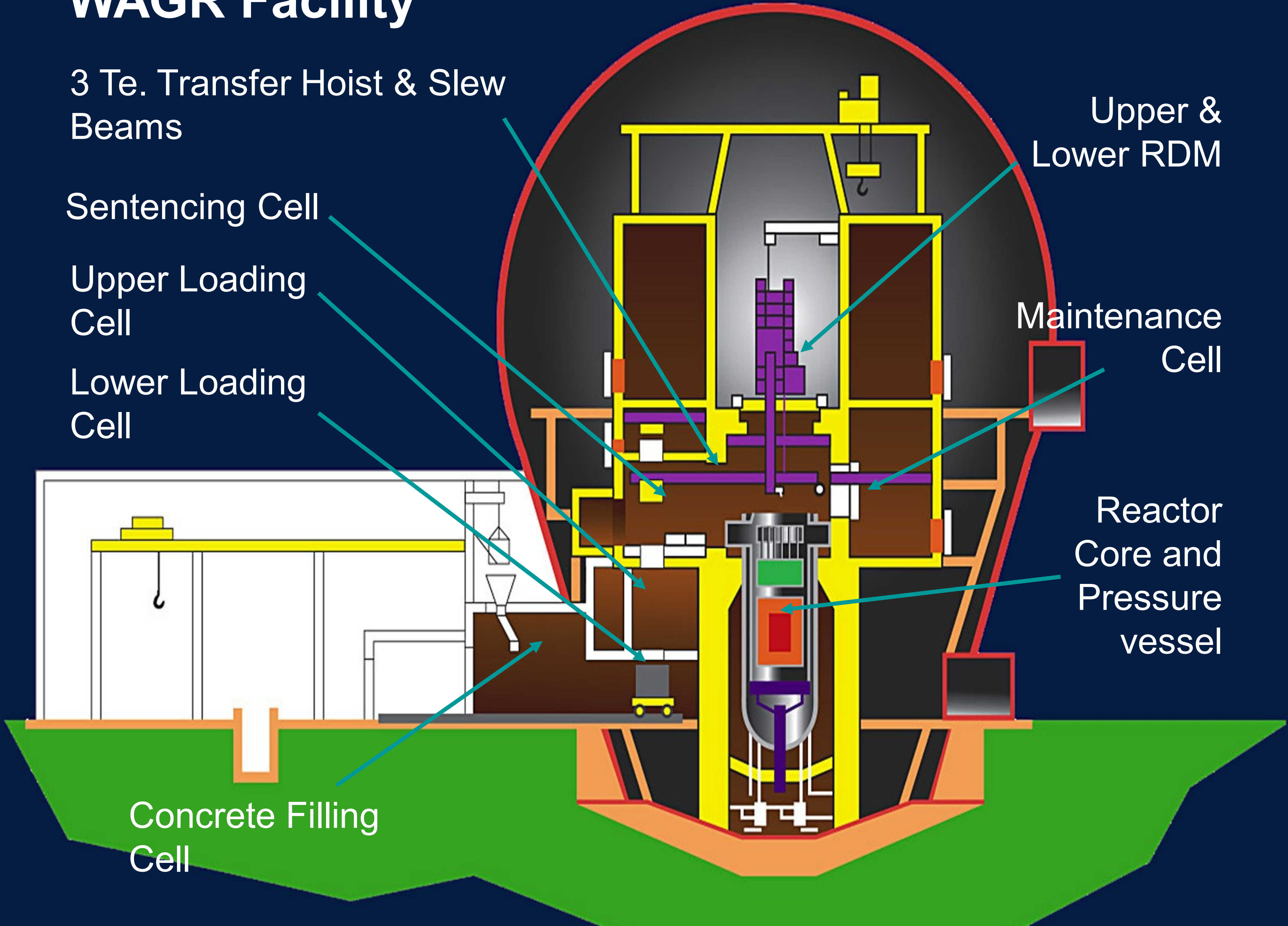
Windscale Advanced Gas Cooled Reactor (WAGR)



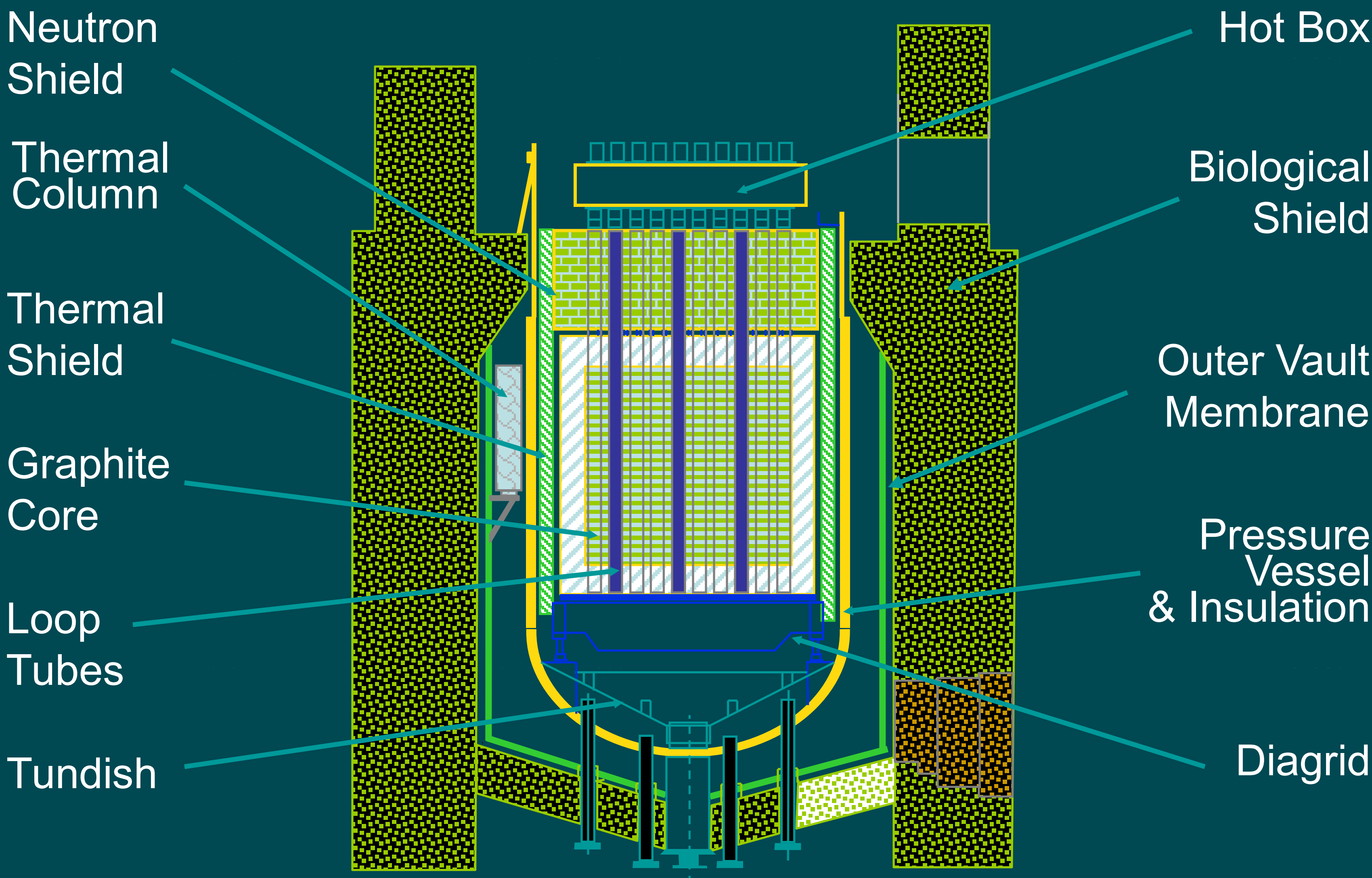
WAGR Basic Design Data

- Prototype for the UK Civil AGR programme
- Reactor first critical 1963
- Reactor Output - 100MW(T) 33MW(E)
- Reactor Graphite Moderated CO_2 Cooled
- Core Dimensions 6m High x 6m Diameter
- Reactor shut down 1981

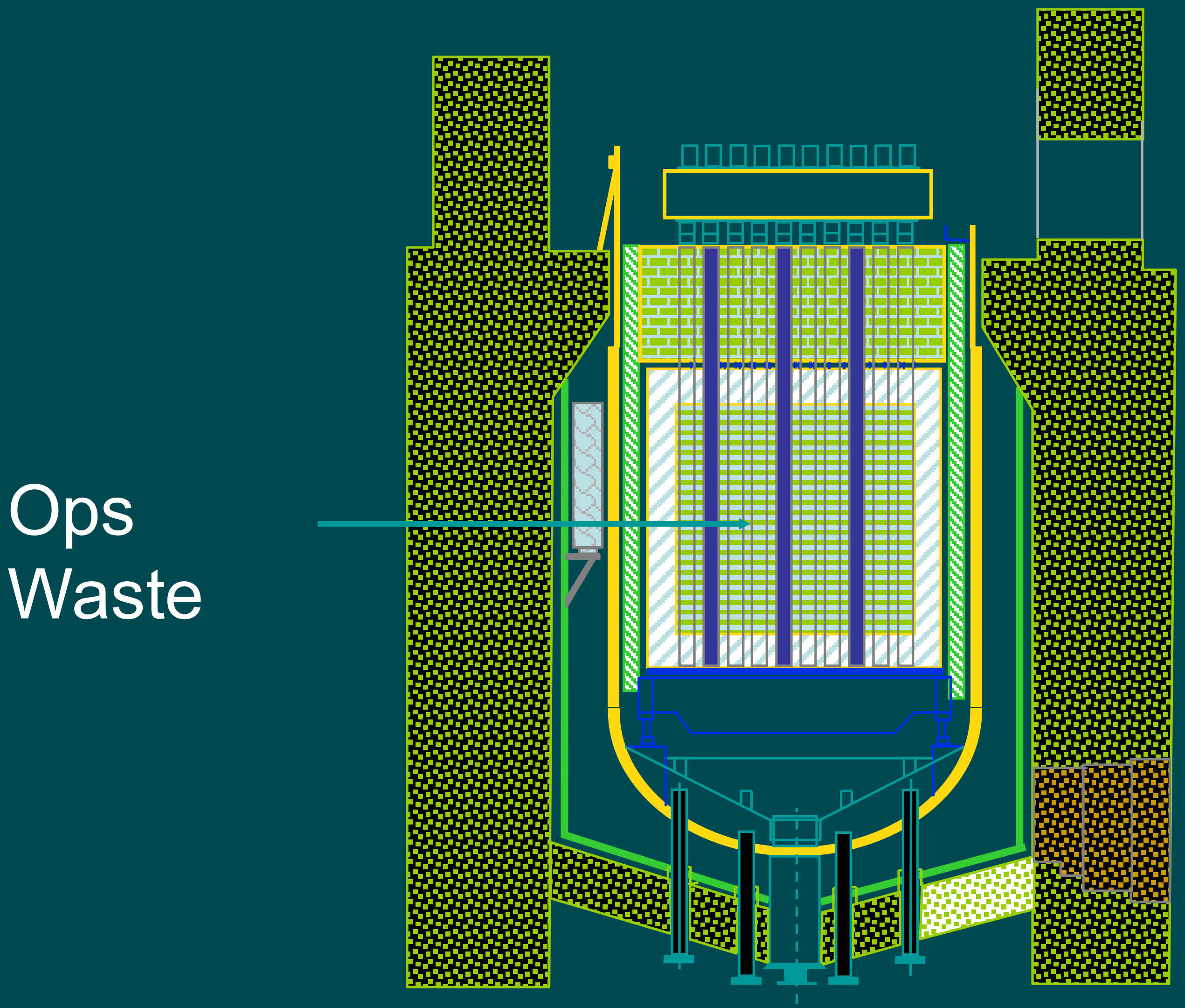
WAGR Facility



WAGR Reactor



Campaign 2 - Operational Waste



Operational Waste Overview

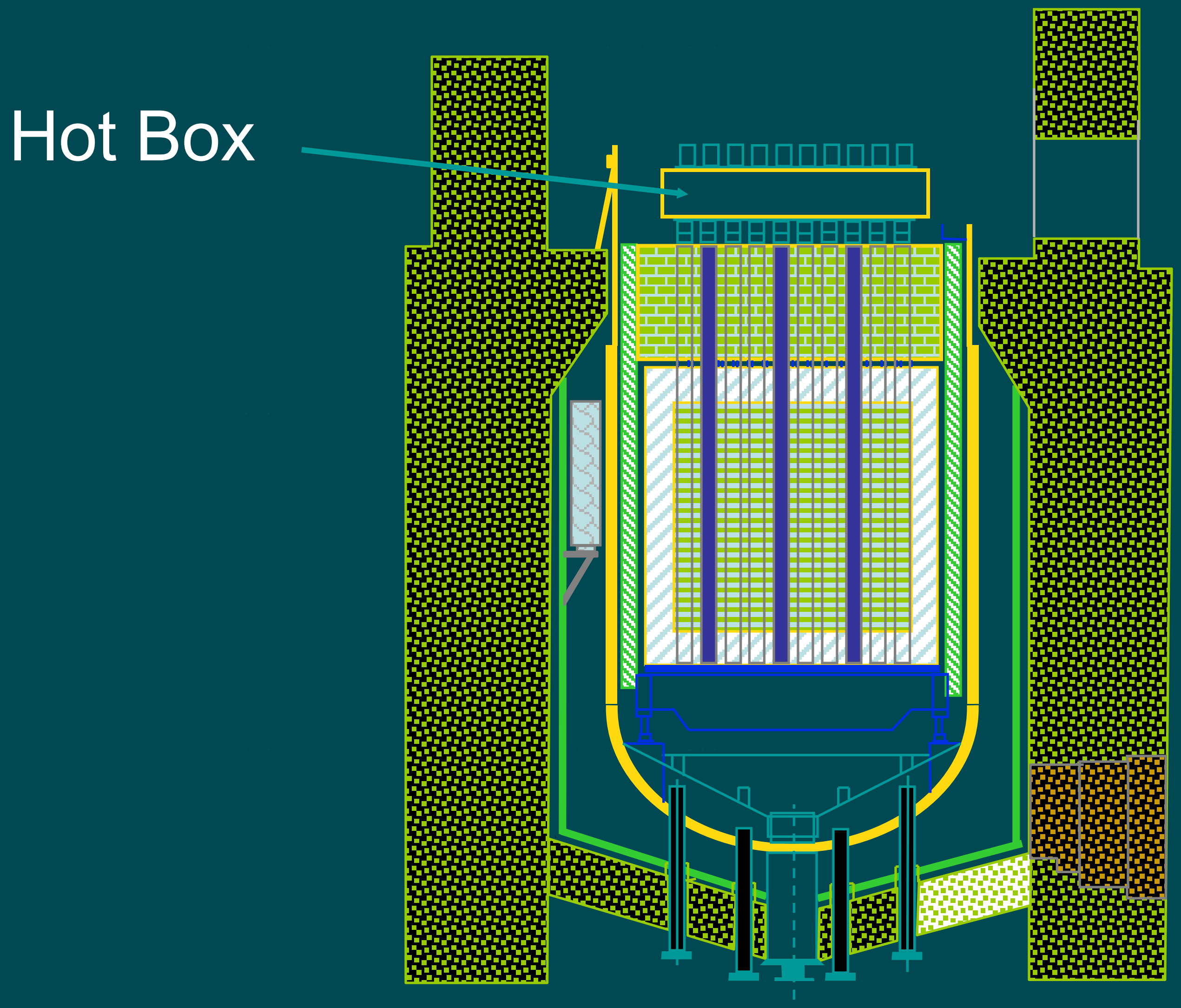
- The WAGR reactor was shut down in 1981 and subsequently de-fuelled. On completion of de-fuelling, various items of ancillary equipment, termed Operational Waste were stored in the vacant fuel channels.
- The waste items, which include Neutron Shield Plugs, Control Rods, Arrestor Mechanisms etc, were shortened where necessary and fitted with lifting adapters prior to them being stored in the reactor.
- A ball grab was used to remove these items from the reactor for encapsulation.

Operational Waste Summary

In total 7 ILW boxes were generated during this campaign and the majority of items of operational waste within the reactor were removed.

Various items which could not be removed, due to them being stuck or having damaged lifting adapters, were removed during subsequent campaigns as they were uncovered.

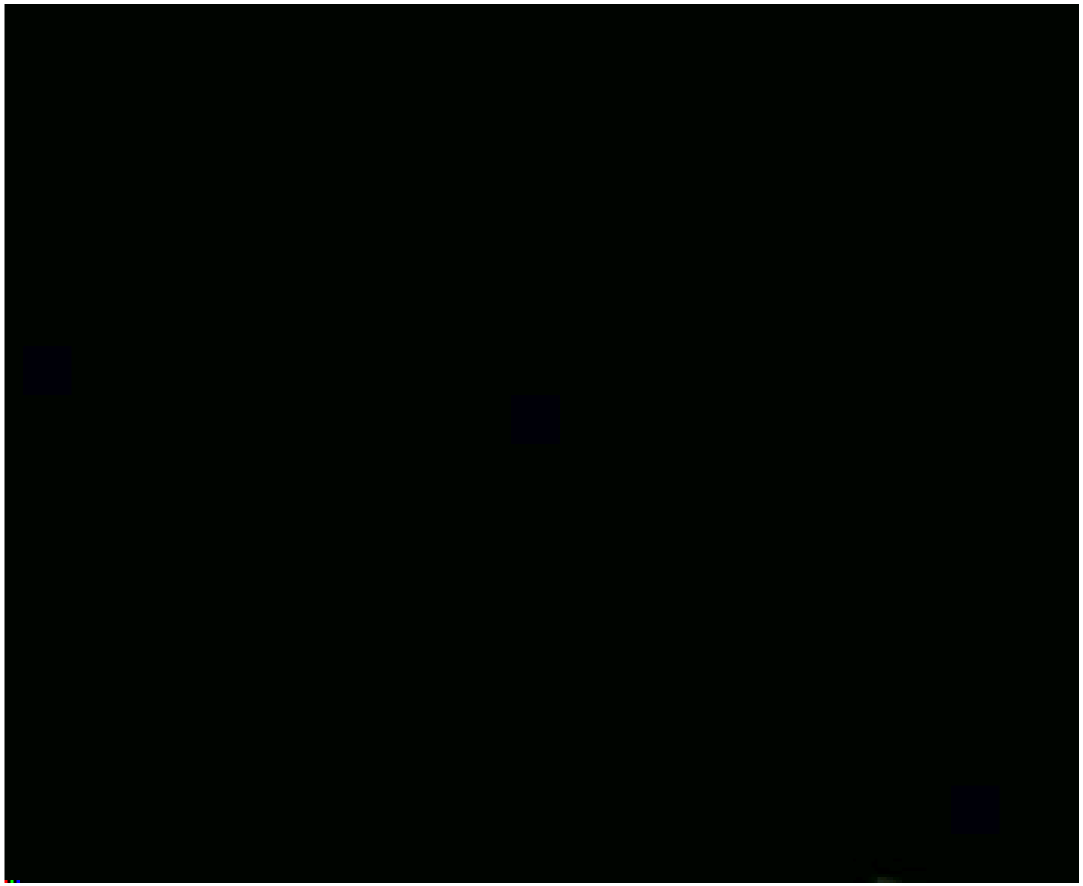
Campaign 3 - Hot Box



Hot Box Overview

- The Hot Box was a large mild steel flat-ended cylindrical vessel, approximately 5 m in diameter and 0.9 m high, penetrated by the 247 refuelling channels and six loop tube channels.
- Its purpose was to distribute the hot coolant gas emerging from the reactor fuel channels to the four heat exchangers.
- The Hot Box Campaign utilised remotely deployed (and where dose rates allowed, manually deployed) plasma arc cutting equipment for size reduction operations.
- A number of remotely deployed plate grabs and ball grabs were used to remove the cut items.

Hotbox Side Wall Semi-Remote Dismantling

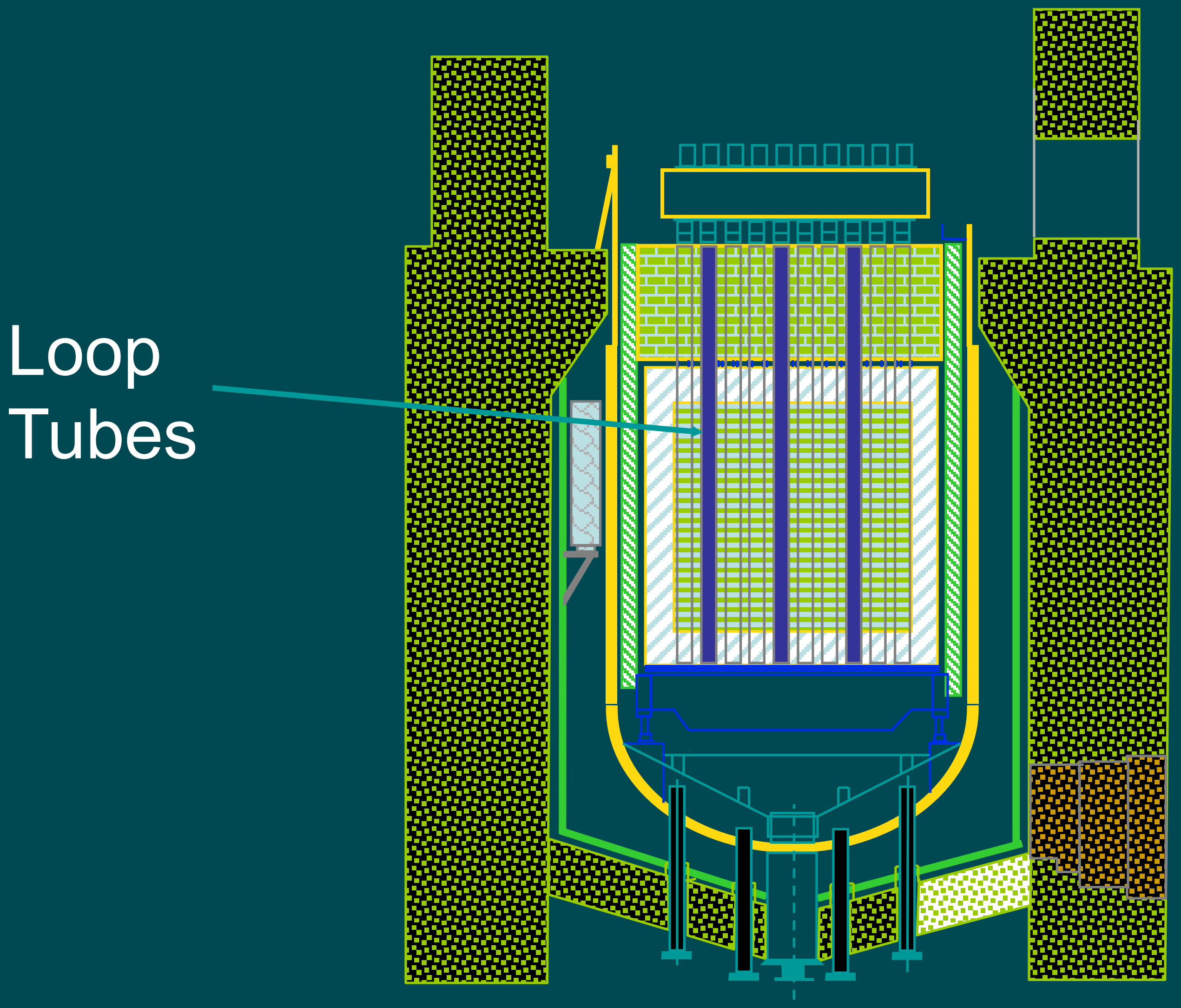


Hot Box Summary

The size reduction & encapsulation of the Hot Box was completed in 14 months.

31 Tonnes of steel waste was removed and 14 Low Level Waste Box were generated during this campaign.

Campaign 4 - Loop Tubes



Loop Tube Overview

- Loop tubes were stainless steel features incorporated into the reactor for experimental work without affecting the normal operation of the reactors.
- The loop tubes were fully independent of each other with each loop tube equipped with separate services.
- There were a total of six loop tubes, four of which were part of the original design, and two of which were installed in 1972.

Loop Tube Overview

- All six Loop Tubes were filled with grout from their base to allow for shearing.
- A 750 te hydraulic shear designed for remote installation and modular assembly was used to shear the Loop Tubes into manageable lengths in a single pass.
- A pneumatic jacking system was used to raise and clamp the Loop Tubes into correct position for shearing.
- Mechanical handling grabs were used to remove the cut sections for encapsulation

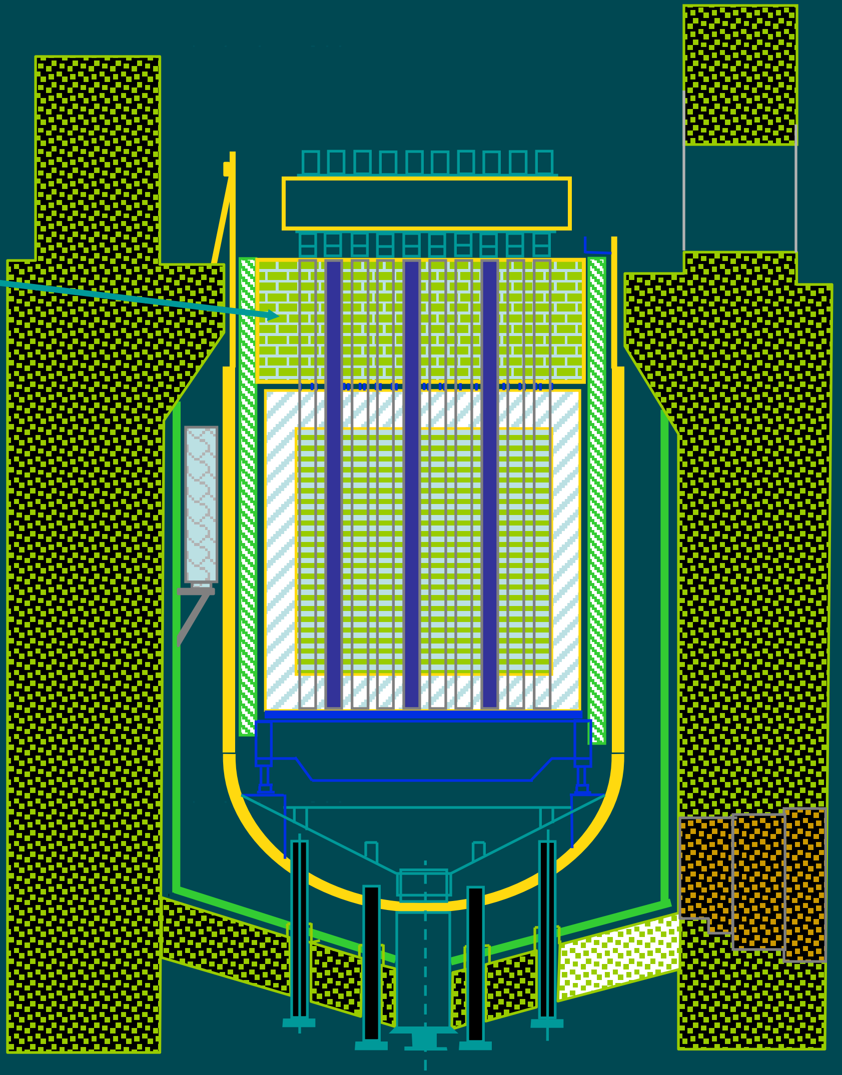
Loop Tube Summary

The size reduction & encapsulation of the Loop Tubes was originally forecast as a 93 day programme and was actually completed in 73 days.

6 Intermediate Level and one Low Level Waste Box were generated during this campaign.

Campaign 5 - Neutron Shield

Neutron Shield



Neutron Shield Overview

- The Neutron Shield comprised of two sections, Inner and Outer, both sections being located above the Reactor Core.
- Its purpose was to reduce the passage of neutrons from the core to an acceptable level at the pile cap and to allow the passage of core re-entry coolant gas from the top of the reactor through the shield.
- A number of manually and remotely deployed cutting tools were used to size reduce various components and ball grabs, vacuum grabs, magnetic grabs and a drill/tap work package were used to remove the components from the reactor.

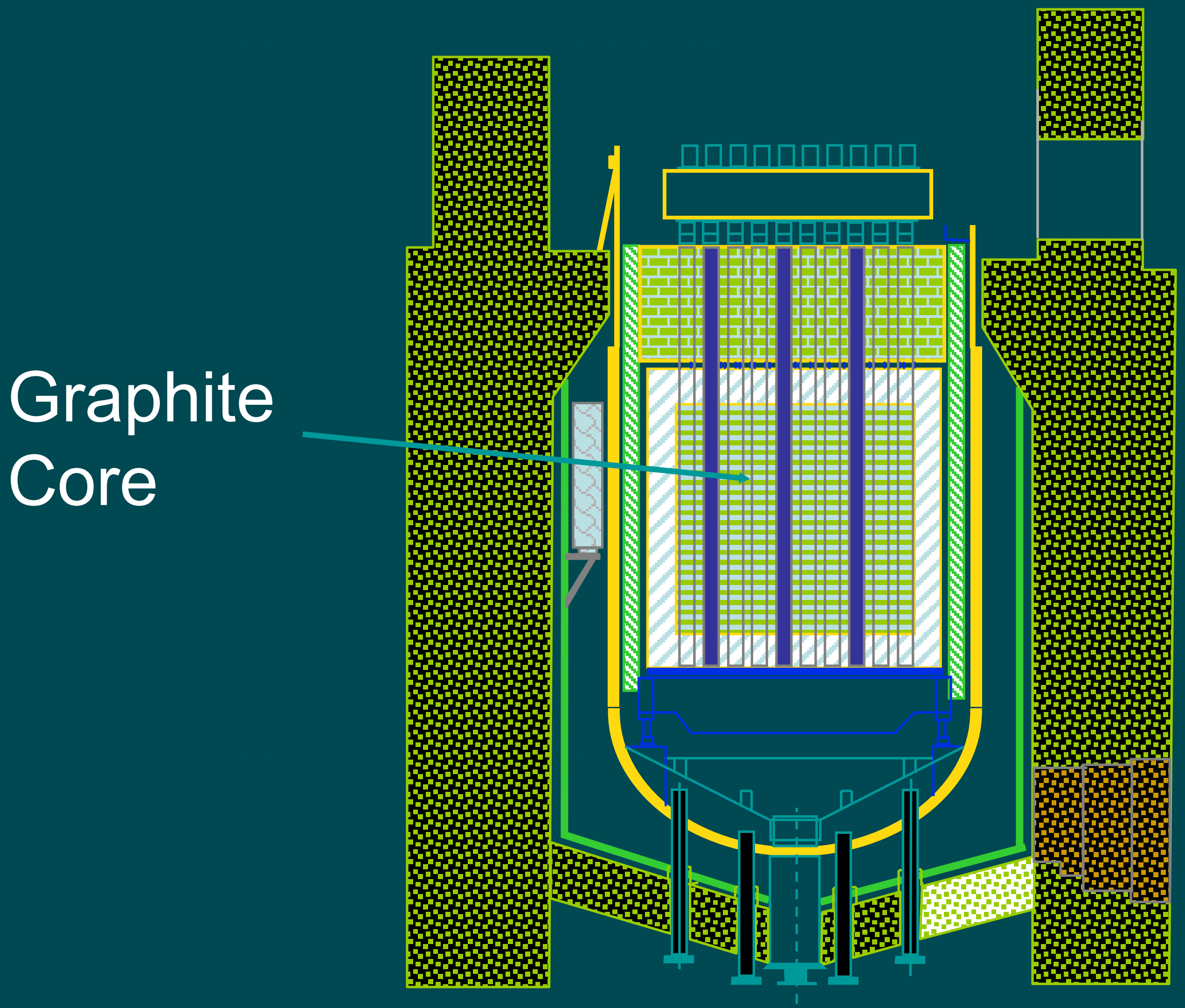
Outer Neutron Shield Graphite Brick Removal Using Drill/Tap Tool

Neutron Shield Summary

The Neutron Shield campaign was planned as a 10 month programme and was actually completed in 8 months.

In total, 73 tonnes of Graphite, plus 35 tonnes of steelwork were packaged into 20 Low Level and 12 Intermediate Level Waste boxes.

Campaign 6 - Graphite Core



Graphite Core Overview

- The Graphite Core was constructed from 3344 graphite bricks in eight layers, each layer being held together by a tensioned steel restraint band.
- Core bricks had vertical holes to form 253 channels. 247 contained fuel elements, control rods and other associated components and 6 channels were for the Loop Tubes. Each brick was attached to its vertical neighbour via a graphite spigot located in recesses in the top and bottom of each brick.
- In vault dose rates from remaining steel components prevented man access – fully remote techniques require attention to detail, mock up and demonstration / training

Graphite Core Brick & Spigot Removal

Graphite Core Summary

The removal of the Graphite Core & Restraint System commenced on 2 May 2002

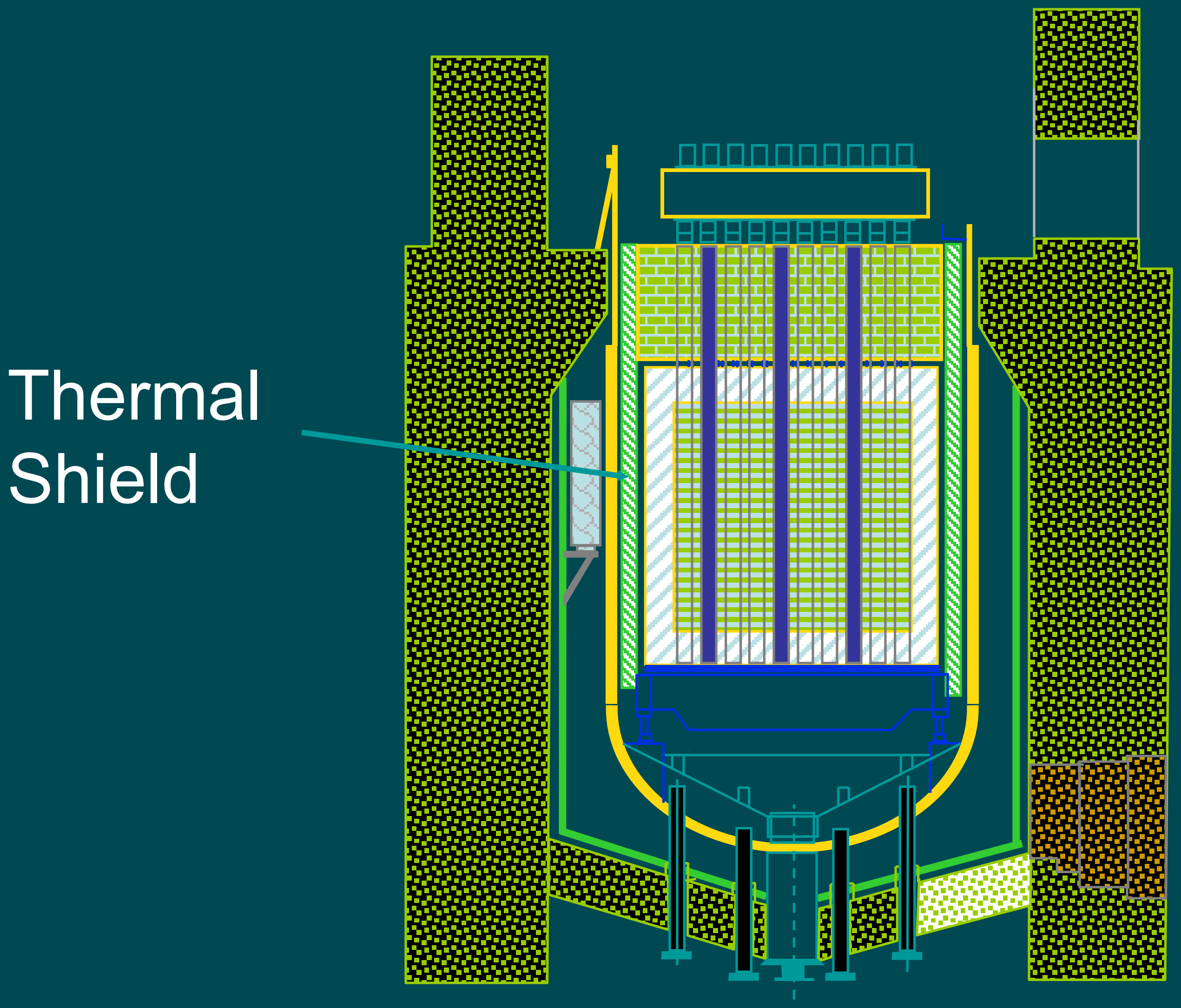
In total 210 tonnes of graphite and 25 tonnes of steelwork were packaged into 17 Intermediate Level and 42 Low Level Waste Boxes

18 months declared programme completed in 10 months

Complex issues were cutting core restraint system and removal of in core instrumentation

Graphite removal ran as a process – disposal waste boxes as close to work face as possible to cut down handling times.

Campaign 7 - Thermal Shield



Thermal Shield Overview

- The thermal shield comprised of fourteen courses of steel ‘bricks’ arranged in a circular fashion between the inside of the pressure vessel and the outside of the graphite core.
- Bricks were radially constrained by fishplates and each had a dovetail type feature that keyed each brick to its neighbour.
- Flux Scanning Tubes and Thermocouples were attached to the inner face of the Thermal Shield and Pressure Measurement Tubing was attached to the outer face.

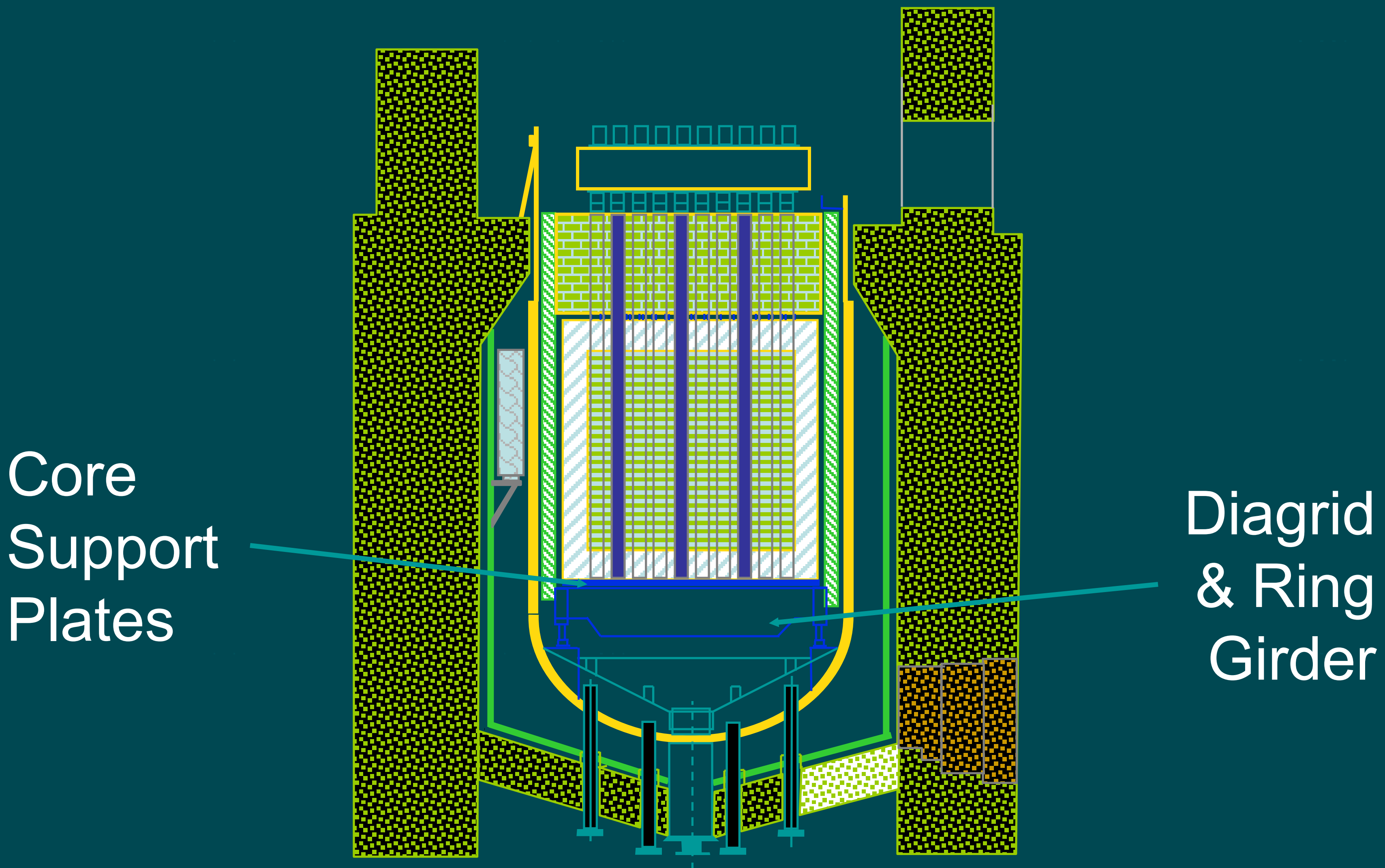
Brick Removal Using Camlok Plate Grab

Thermal Shield Summary

The Thermal Shield Campaign commenced in February 2003 and was completed within 11 weeks.

In total, 180 tonnes of steelwork were removed and packaged into 21 Waste boxes.

Campaign 8 - Lower Structures



Lower Structures Overview

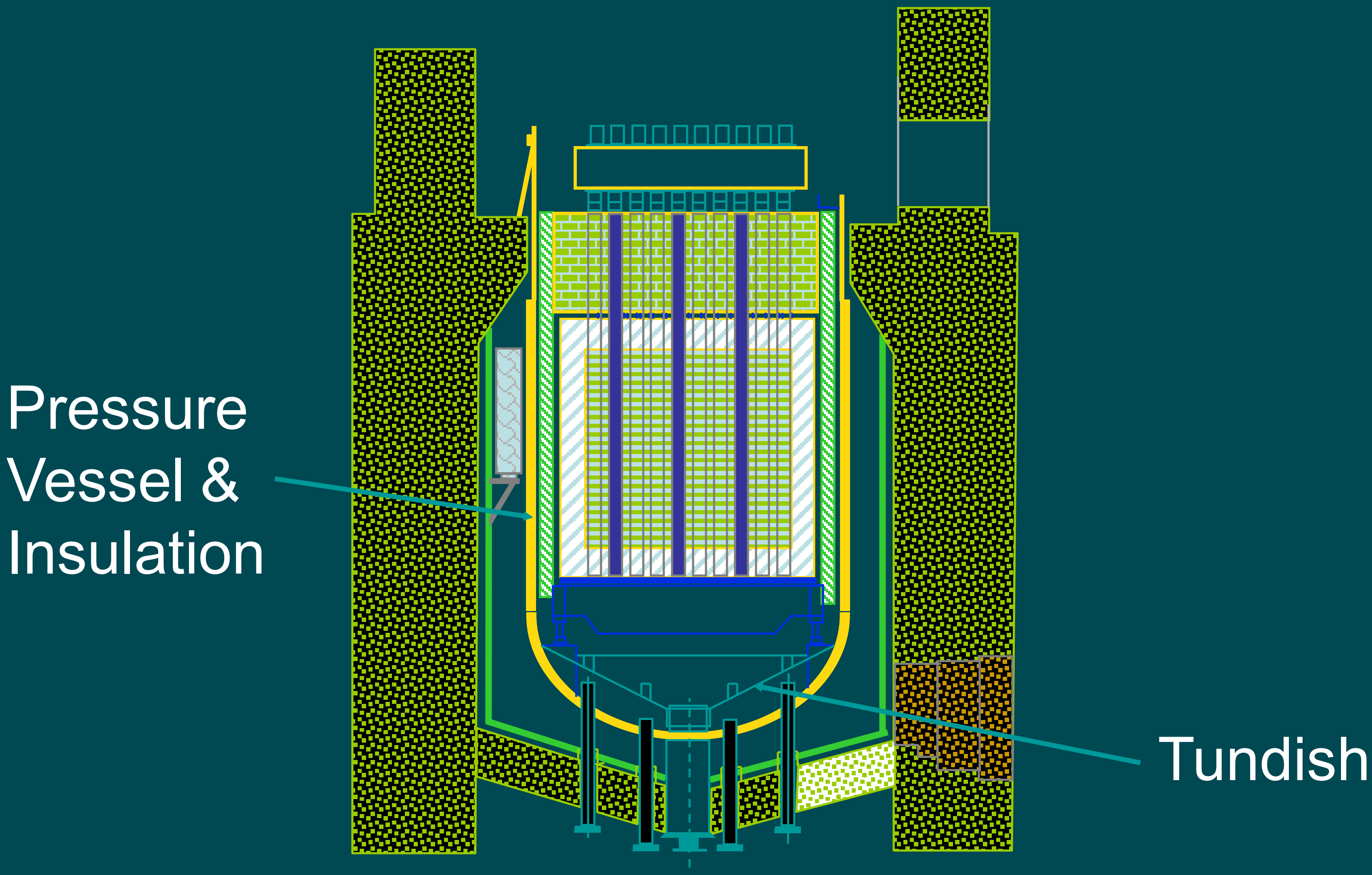
- The lower structures comprised of the support structures which supported the Reactor Core
- They comprised of a hexagonal/triangular lattice (known as the Diagrid) fabricated from 57mm thick steel plate either 914mm or 381mm deep.
- The lattice supported the Core Support Plates and was itself attached to the Diagrid Ring Girder which was a fabricated box section.

Lower Structures Overview

- The Campaign was split into two sections
- The first dealt with the mechanical disassembly and removal of the items above and between the Diagrid Lattice
- Items were disassembled and removed using a variety of remotely deployed tools and grabs
- The second stage involved the size-reduction and removal of the Diagrid Lattice and Ring Girder
- The size reduction was achieved by utilising a purpose-built, remotely deployed oxy-propane cutting system

Core Support Plate Removal

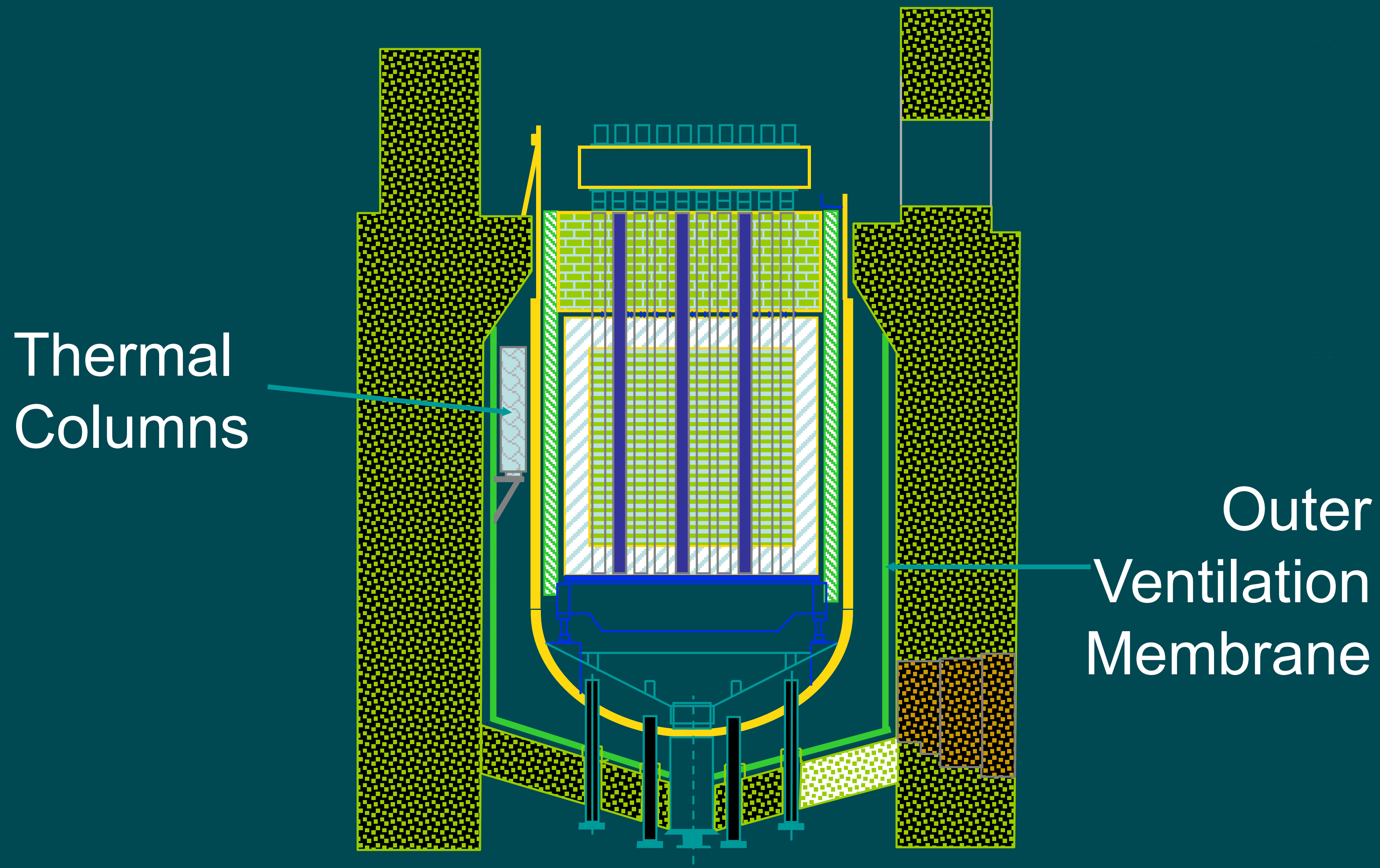
Campaign 9 - Pressure Vessel & Insulation



Campaign 9 – Pressure Vessel & Insulation

- Consists of the steel pressure vessel which is, on the whole, 73mm thick.
- The majority of the vessel is clad in asbestos-bearing insulation which covered in a chicken- wire and cement screed with an outer cladding of aluminium sheet, the total thickness of the cladding being 216mm.
- In addition to the pressure vessel itself, the campaign also removes the tundish (76mm thick steel plate)and vessel support strakes and severs a number of tubular penetrations into the lower hemisphere of the vessel.

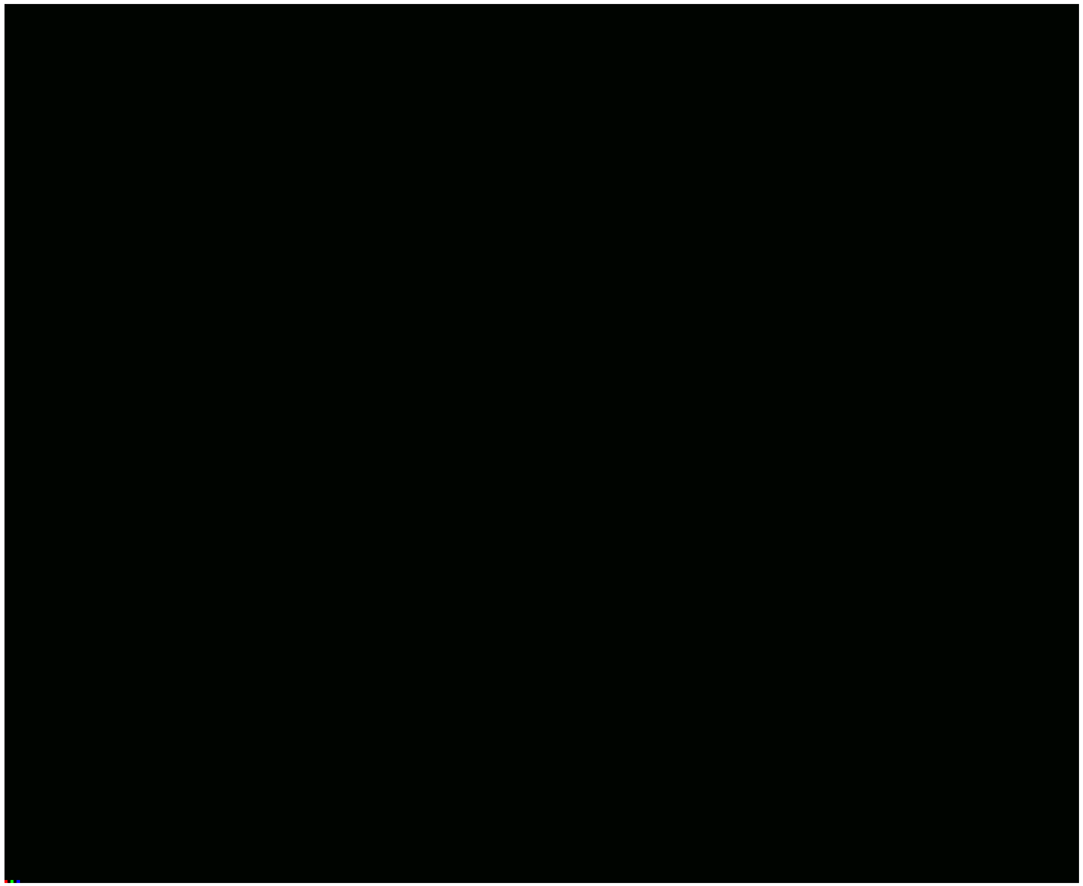
Campaign 10 - Thermal Columns & OVM



Campaign 10 – Thermal Columns & Outer Vault Membrane

- Thermal Columns are two columns of graphite bricks situated between the pressure vessel and the bioshield. The bricks are supported by steelwork brackets attached to the bioshield.
- Outer Ventilation Membrane is a 3mm thick mild steel curtain wall sheeting arrangement which covers the bioshield wall and floor and is supported by a mild steel support structure which is attached to the bioshield.

Waste Encapsulation



Lessons Learned

- It is possible to decommission a nuclear power plant reactor as a commercial venture
- The more effort put into understanding the problem the greater the project return – small details can be very important
- Use of Local Labour - Leads to low turnover of staff and allows for flexibility of working
- Management of Project Risks - Frequent attention to the management of risks and their mitigation
- Rehearsals - The necessity for exhaustive, realistic trials is an essential part of the WAGR project
- Optimising dismantling as a process gave great programme and hence cost benefits.

General Lessons Learned

- Simplicity - Keep it simple
- Contingency - Always have a plan B and if necessary a plan C!
- Techniques developed in management and engineering could be applied to other nuclear decommissioning projects

General Lessons Learned

- Our Client is an "Intelligent Customer" - we manage his expectations by keeping him involved in development of the T&M and Safety Case. This need not mean that we should not be more challenging of his expectations.
- It has been demonstrated that letting contracts for development of T&Ms years in advance can be unwise as circumstances change and knowledge increases throughout the project.

General Lessons Learned

- Letting “turnkey” T&M Contracts does not always achieve workable solutions. Through experience we were the experts at decommissioning WAGR and are therefore best placed to develop T&M’s. Requires more engineering resource but small expense compared to the cost of down-time caused by unworkable solutions - also enables full control/ownership of risk.
- If time constraints dictate that development of a full campaign will lead to a delay in the start of operations, split the campaign up into more manageable sections

General Lessons Learned

- Initial project definition is very important to avoid getting something that you don’t want.
- ‘Co-location’ works! e.g. Next door desks, same office, same site, the closer the better.
- By carrying out the whole process from dismantling to encapsulation enables us to have total control of our progress as we are not reliant upon separate waste processing facilities.

General Lessons Learned

- When taking over a project, ensure that any inherited equipment is fit for purpose - we had to carry out extensive modifications to some of the installed equipment at WAGR as it is now operating beyond its original design life
- The RDM was designed to be operated by a “man off the street” and is overcomplicated by extensive use of interlocks which have proved problematic - the realisation that the equipment would be operated by skilled operators would have led to a much simpler design and ultimately higher reliability of the equipment

General Lessons Learned

- Use of local labour - leads to low staff turnover and a very flexible workforce who are willing to change working patterns at short notice
- Use of local sub-contractors for tooling design and manufacture saves travelling (and therefore risk of accidents) and time of Engineers
- Project Engineers keep ownership of Campaigns until completion - leads to better definition of deliverable requirements

General Lessons Learned

- Great success in a series of campaigns does not guarantee success in subsequent ones.
- Lack of adequate and representative works tests cause subsequent deployment delays due to unexpected behaviour of the tooling.

General Lessons Learned

- Lack of adequate training facilities and time for operators on complex equipment causes mistakes and delays to the programme. Involvement of operations staff in all phases of design and testing.
- When installing ancillary plant too much reliance can be placed on ‘expert’ contractors without ‘in house expertise’ to question the knowledge. We need to become the ‘experts’, via ‘homework’ if necessary, or by better use of Company resources.
- Premature dilution of expertise to other projects can cause disruption and delay.

General Lessons Learned

- Insufficient management of Stakeholders' expectations. e.g. neglecting to highlight the difficulties of the some of the tasks such as hot cutting (hotbox, lower structures, PV and I).
- Decommissioning can be R and D dominated and as such planning cannot be accurately forecast. Accuracy of planning can only be achieved when operations are 'steady state'.
- Use of inherited equipment should be reviewed for current and future effectiveness and modified or replaced as appropriate.

Was the WAGR Project a Success?

- Safety - Without being safe the project cannot be a success. Eight years without lost time accident
- Dose Uptake - Minimised, in 2003, less than 1.4mSv to any single individual, total 17.7mSv for whole of project personnel
- Technical - Simple and practical solutions to arising problems
- Was the WAGR Project a Success - YES!

Thank you