

DISMANTLING THE WINDSCALE ADVANCED GAS COOLED REACTOR PRESSURE VESSEL AND INSULATION - DESIGN AND DEVELOPMENT

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ABSTRACT

Progress on Project WAGR-Decommissioning the Windscale Advanced Gas Cooled Reactor has reached a major milestone with the letting of the contract for the provision of tooling and methodologies to enable the Reactor Pressure Vessel and Insulation (PV&I) to be dismantled.

This paper describes the design and development phase of the contract, explaining briefly the preferred methodology and detailing first tests performed to check the feasibility and the efficiency of the chosen dismantling processes, before undertaking the design.

INTRODUCTION

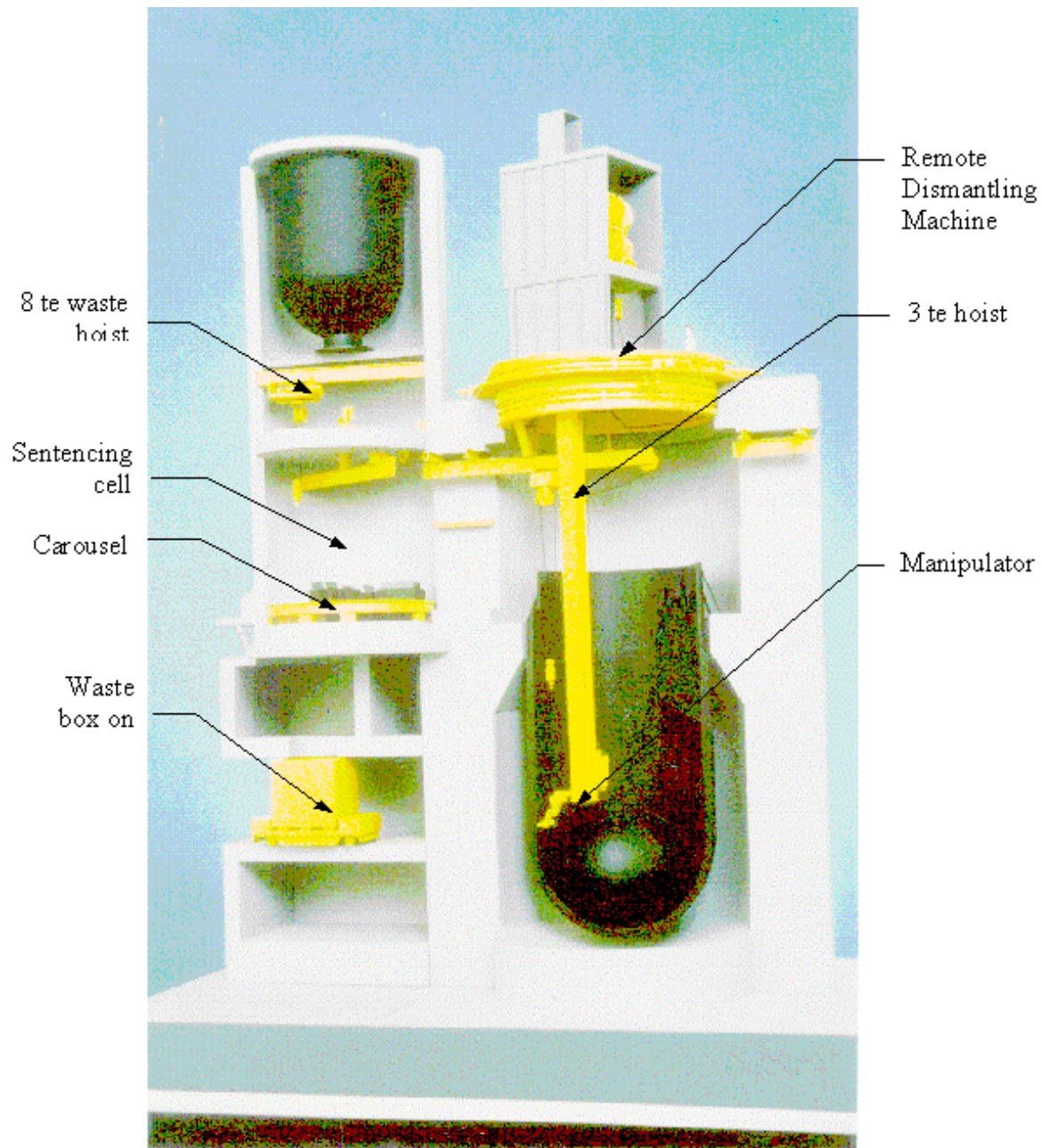
The 33MWe Windscale Prototype Advanced Gas Cooled Reactor was shut down in 1981. In order to prove the feasibility of reactor dismantling, UKAEA undertook to decommission the facility. The WAGR Decommissioning Project is jointly funded by the UK Department of Trade and Industry and Magnox Electric plc, with a contribution from the European Commission. UKAEA is managing the Project on behalf of the Stakeholders, using Industrial Contracting organizations to undertake the decommissioning work. On the present schedule the core and the vessel should be completely removed during Phase 1 of the project. In all about 1200 te of material will be removed.

In the interests of making the project commercially minded and cost effective the dismantling project is split into some ten decommissioning campaigns, each campaign requiring separate safety clearance. Each decommissioning campaign is defined by an associated Tooling and Methodology (T&M) contract. The T&M contracts promote involvement from outside companies, encouraging technical forethought combined with competitive bidding.

European Nuclear Technologies Ltd (ENTECH), a joint venture between SGN (a subsidiary of COGEMA) and Strachan & Henshaw (a subsidiary of the Weir Group), has won one of the most technically demanding projects for the provision of T&M to enable the dismantling of the Pressure Vessel and Insulation (PV&I). The three year Contract is to develop the methodology and manufacture necessary tooling to remove the PV&I, and package them with concomitant debris for disposal to Nirex and Drigg. Encompassed within the Contract is the provision of training and site technical support for the actual dismantling campaign, the latter being scheduled for a duration of 17 weeks.

The PV&I decommissioning campaign will commence after the internal components of the pressure vessel have been removed. The dismantling of the reactor internals will be carried out using the Remote Dismantling Machine (RDM) (designed and built by Strachan & Henshaw Ltd) which forms a containment structure incorporating the reactor compartment in which remote handling tools are deployed by a remote manipulator arm. (see Fig. 1 below).

Figure 1. Model showing section through the WAGR Waste Route

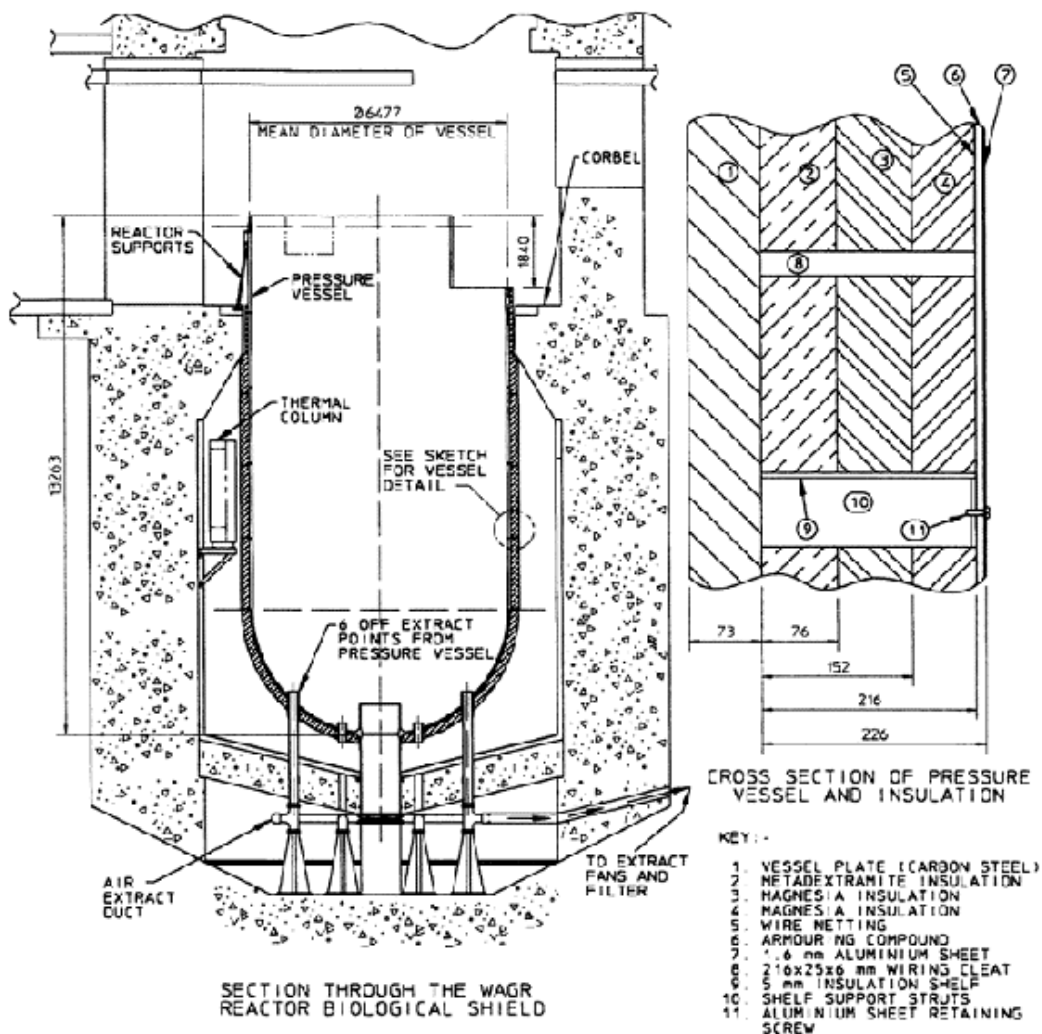


DESCRIPTION OF THE PRESSURE VESSEL & INSULATION

The pressure vessel (PV) is manufactured from carbon steel plate which varies in thickness from 44mm to 111mm. It is of cylindrical shape with a hemispherical base. The average diameter of the PV is 6.5m and its total length 13.0m (Fig. 2 below).

The insulation is attached to the outside of the PV. It is supported on carbon steel shelves and is wired in place with the aid of cleats. It comprises three layers of insulation blocks, a galvanized wire mesh, a thick layer of armouring compound, and an external covering of aluminum sheet. The insulation layers are made of Metadextramite and Magnesite insulation which both contain asbestos. The thickness of the insulation layers varies along the reactor from 76mm in the corbel region to 226mm for the remainder. The clearance between the outside of the insulation and the inner surface of the reactor building are limited (generally 932mm, reducing to 76mm near the top region).

Figure 2 Details of Pressure Vessel & Insulation



AVAILABLE OPTIONS FOR PV&I DECOMMISSIONING

Taking into account the specific features of the WAGR pressure vessel, its environment and the existing dismantling equipment currently on site, ENTECH examined different solutions. Many solutions were considered by ENTECH, with the following main options being taken forward for further assessment:

- Lifting out the pressure vessel and then undertaking cutting operations
- Using the RDM for cutting and material removal operations
- Cutting sections of the PV&I thermally, mechanically, or by water jetting
- Using a combined cutting process (mechanical and thermal)

During the selection of the cutting process, particular attention was given to the following specific design requirements:

- Nature, thickness and variety of the material to be cut and handled
- Minimizing the amount of liquid waste during operations
- Integrating the equipment into the available space envelope, utilizing existing equipment
- Amount of airborne debris

After extensive review, the method selected was to use the existing RDM and consider a combination of mechanical cutting and flame cutting processes, evaluating both options to determine the optimum process.

The solutions have been assessed considering the following considerations:

- Safety
- ALARP
- Risk
- Efficiency
- Decommissioning timescale
- Simplicity of design and operation
- Cost of equipment and implementation
- Use of existing equipment and information

DEVELOPMENT OF THE PREFERRED SOLUTION

As a fundamental part of the project, a series of tests were undertaken to prove the feasibility of the preferred solution and to demonstrate that the tools will successfully work during the actual decommissioning operations. A risk management approach is being implemented and is considered an integral part of every stage of the development. A risk assessment is performed at key stages of the project to check that all potential failures have been identified and analyzed, determining whether corrective action is necessary in order to minimize their impact. This approach minimizes the risks throughout the Contract and in particular at the beginning of the decommissioning operations themselves.

Currently three stages of tests have been identified as summarized below. The first and second stages have already been successfully completed, the results being incorporated into this report.

- First series of cutting/removal tests using similar materials representing as close as possible sections of the real pressure vessel and insulation. The objective is to establish the feasibility and the efficiency of the combined process.
- Second series of cutting tests using remote operation more precisely simulating site conditions, the main objective being to establish the repeatability of cutting with fixed and optimized parameters.
- Third series of cutting/removal tests simulating as close as possible the remote operations, on a scale mock up. The objectives are to confirm the operation conditions and to train the operators.

DETAILED TESTS PERFORMED

A series of tests have been carried out at the Faverdale Technology Centre with the involvement of Darchem, specialists in the manufacturing of insulation materials for UK reactors and at ENTECH in Bristol, UK

Through analyzing technical literature and undertaking initial comparison trials, representative materials were selected which are the same or more onerous than the actual materials. Full consideration was given to ensuring that, as far as practicable, the actual material conditions were recreated during the cutting tests.

Representative test pieces measuring 1.2m x 1.2m x 300mm were produced, the insulation material used in place of the metadextramite and magnesia was Newtherm 800. The armouring compound selected was Cape Superset AC1.

The tests, undertaken in a test cell measuring 5m x 3m x 3m, included both flame cutting and cutting with disks.

Typically, the following data was collected throughout the trials:

- Nozzle size and type - Flame cutting
- Gas flows and pressures - Flame cutting
- Powder flow rate during powder injection - Flame cutting
- Optimum cutting disk - Disk cutting
- Cutting force - Disk cutting
- Fallen debris produced
- Amount of airborne debris
- Cutting speeds range
- Quality and characteristics of cut

Arisings Monitoring During Cutting Operations

During the trials, the arisings were monitored, this being broken down into three areas:

- Debris monitoring - Fallen debris.
- Ventilation monitoring - Fumes that were drawn through the ventilation system.
- Dust monitoring - Selected tests to measure airborne dust present in the test cell.

SELECTED RESULTS OF TRIALS PERFORMED

Cutting Techniques

The cutting torch assisted by powder injection, was found to cut through the composite comprising 75mm thick steel and 225mm thick insulation. The torch was also successful at cutting through a double (150mm) layer of steel with the accompanying insulation.

The disc cutting process using coarse hard grade aluminum oxide, as well as diamond disc, was found to be effective at cutting through the insulation material, however the dust produced was found to be considerable such that the test samples were no longer visible.

Through mechanically cutting the insulation prior to flame cutting, it is possible to carry out flame cutting without the need for powder injection. However, this did not offer a reliable cut. The results of the disc cutting trials are available, although not covered within this paper as this option has not been selected for decommissioning operations.

In excess of 70 cuts were undertaken during the trials to prove the reliability and supply data of the potential cutting methods. A selection of the results from flame cutting with powder injection are summarized in Table I below.

Table I. Summary of Flame Cutting Results

Test Nos	Nozzle Type	Nozzle stand-off mm	Oxygen pressure bar	Propane pressure bar	Powder injection & flow rate		Cut Length mm	Mean entry Kerf mm	Mean exit Kerf mm
					bar	kg/hr			
1.1	DB 318	50-60	14	2	0	0	300	24	0
1.2	DB 318	50-60	14	2	0.5	25	450	16	42
1.3	DB 318	50-60	14	2	0.5	25	760	19	44
1.4	DB 318	50-60	14	2	0.25	13	130	11	45
			14	2	0.4	17	630		
1.5	DB 318	10-20	14	1.38	0.45	20	590	8	77
			14	1.38	0.55	27			
1.6	DB 318	50-60	14	1.38	0.55	27	330	5	68
1.7	DB 318	60	14	1.38	0.55	27	510	6	61
1.8A	DB 318	40-50	14	1.38	0.55	27	350	11	61
1.8B	DB 318		14	1.38	0.55	27	220	9	46
1.8C	DB 318		14	1.38	0.55	27	170	7	61
1.10	DB 618	50-60	14	1.38	0	0	130	21	0
5.5	DB 318	40-70	14	2	0	0	760	17	52
5.6A	DB 318	50-70	14	2	0	0	490	9	27
5.6B	DB 318	100	14	2	0.5	25	330	13	80
5.6C	DB 618	100-150	14	1.04	0.5	25	350	18	36
5.6D	DB 618	80-130	14	1.04	0.5	25	290	13	51
5.6E	DB 618	70	14	1.04	0.5	25	220	14	74
5.6F	DB 618	70-130	14	1.04	0.5	25	220	23	69
5.6G	DB 618	110-120	14	1.04	0.5	25	240	22	76

Table II. Summary of Flame Cutting Results

Test Nos	Cut Length (m)	Magnetic material (g)	Non magnetic material (g)	Filter Loading (g)	Total debris (g)	Debris / metre (kg/m)
1.1 & 1.2	0.75	7116.0	81.6	29.3	7226.9	9.64
1.3 & 1.4	1.52	6224.1	300.7	28.2	6553.0	4.31
1.5 to 1.8	2.17	16693.1	1177.3	31.5	17901.9	8.25

The debris produced during the cutting trials (1.1 to 1.8) was recorded in order to quantify the levels of debris that may be produced during the dismantling operations. Table II summarizes the debris produced during the trials, the average amount being 7.1 kg/m, which equates to a total of 5 tonnes of fallen debris. This debris will be collected using a selection of grabs.

Plate Grab Trials

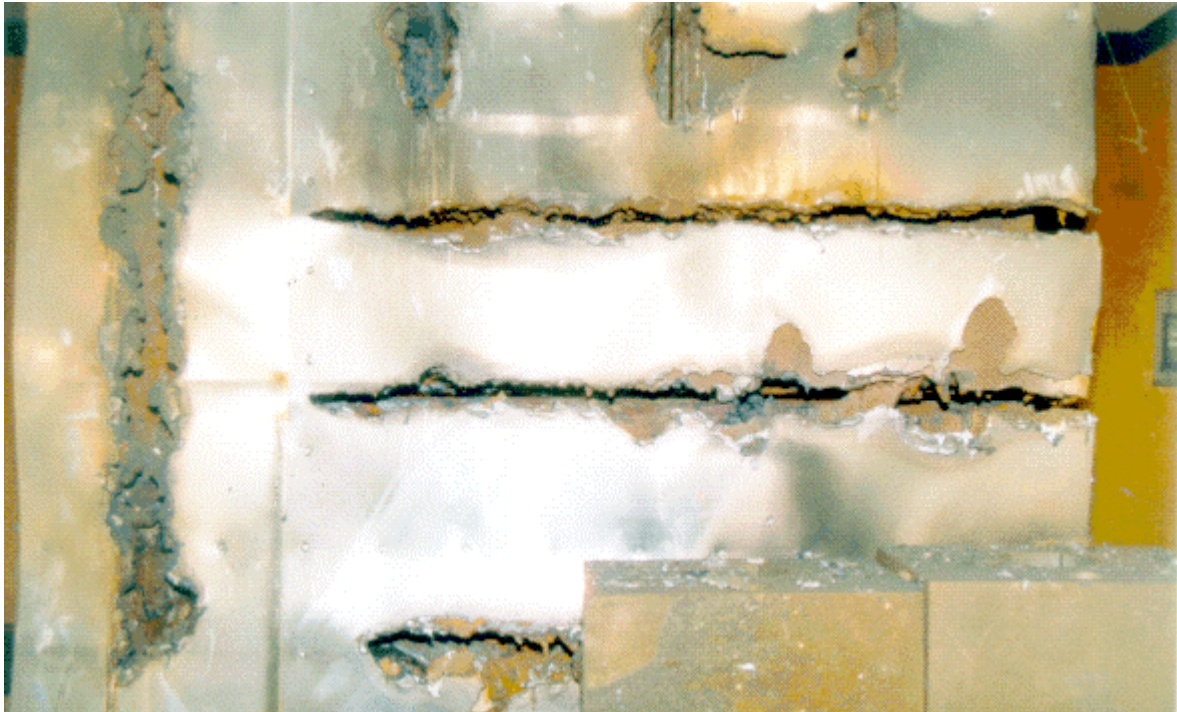
In addition to undertaking the cutting trials, a sequencing block grab was tested on a cut section of a PV&I test piece. The single grab operated successfully lifting a load in excess of 700kg, without slipping or crushing the insulation.

Photographs of the flame cutting with powder injection and a section through a test piece are shown in Figs. 3 and 4 respectively.



Figure 3) Remote flame cutting with iron powder injection - successful at reliably cutting through a 300m composite of steel and insulation.

Figure 4) Reverse side of test piece showing exit kerf through aluminum sheet after flame cutting with powder injection. The graphite blocks represent the thermal column, these were unaffected by the cutting process.



DESIGN CONSIDERATIONS & PROBLEMS

In taking the design and methodologies forward, it is important to make full use of existing equipment and ensure that the new tooling interfaces with the existing equipment. The main parameters set for the design are:

- Demonstrate that all tooling and methodologies are safe and ALARP.
- Equipment is to be robust and reliable.
- Utilize existing equipment where possible.
- Make full use of proven technology.

The specific equipment to be considered during the contract includes:

- The cutting system.
- Modifications to existing gas suppliers and services.
- Grabs.
- Waste box furniture.
- Ventilation and control of asbestos material.
- Interfacing with the existing control system.

In developing the solution a number of areas require investigation, these include:

- Ensuring that the lower PV supports are adequate to support the PV once the upper supports are removed.
- Ensuring that the ventilation system is adequate.
- Contain the spread of asbestos material.
- Assess the temperature during cutting operations and ensure equipment is not adversely affected.

DESIGN SOLUTIONS/ONGOING DESIGN WORK

Through the extensive trials, undertaking the detailed studies and giving full consideration to the design parameters, the final design has been reached.

Summarized Methodology

Reference Fig. 1, model showing a section through the WAGR waste route. Sections of the pressure vessel and insulation are cut using an oxy-propane cutting torch with powder injection, mounted on a manipulator. The manipulator with a teach and repeat facility is operated from within the control room where the working areas are viewed by CCTV.

Each section of the PV&I will take on average 20 minutes to cut, sections being removed by the 3te hoist, fitted with the chosen grab for gripping the plate. The 3te hoist raises the cut plates and transports them through the waste route to the sentencing cell, placing the plates into the waste box furniture (waste racks).

When full, a waste rack is raised using the 8te hoist. The carousel rotates to allow the waste rack to be lowered through an opening and the waste rack is deposited into the waste box below. The boxed waste is then grouted and taken away for disposal.

The campaign duration for removal of the PV&I is 17 weeks, this time cycle is driven by the grout curing time for each waste box, this being a period of 48 hours.

Basic Torch Design

The cutting method selected is an oxy-propane torch with iron powder injection. The basic parameters are summarized in Table III below.

Table III. Gas and Powder Consumption

	Torch Consumption	Pressures	*Campaign Consumption
Cutting Oxygen	50m ³ /hr	10bar	7000m ³
Heating Oxygen	10m ³ /hr	1bar	inc. in above
Propane	4.5m ³ /hr	0.3bar	500 m ³
Powder (iron)	25kg/hr	-	2800kg

* Campaign consumption based on 106 hours total cutting time, plus a 10% contingency.

The torch, mounted on a remotely operated manipulator is fitted with the following equipment:

- Heat shield
- Ignition unit
- Stand-off detector
- Flame detection

To facilitate the cutting equipment, new gas and powder supply lines need to be provided through new routes onto the RDM via spring loaded reeling drums and down the mast to the manipulator mounted on the platform.

BASIC GRAB DESIGN

A selection of grabs are being developed from already existing proprietary grabs. The grabs proposed are summarized below and are designed for both normal operations and for fault cases.

Grabs i) to v) are plate clamps. The jaws are operated by an electric actuator and the gripping force provided by the self weight of the plate. They cover all of the normal operations.

i)	plate thickness	40-72mm
ii)	plate thickness	64-96mm
iii)	plate thickness	90-122mm
iv)	plate thickness	285-335mm
v)	plate thickness	265-315mm

Grabs vi) to viii) are more classical plate grabs to pick up plates in the horizontal position. They are to dropped plates which have landed insulation side upwards.

vi)	plate width	600-900mm
vii)	plate width	800-1100mm
viii)	plate width	1000-1300mm

Grab ix) with a capacity of 4000kg, is a proprietary 400mm diameter magnetic grab with a curved pole face capable of picking up any of the plate sections provided they have landed with the concave face upwards.

Grabs x) to xv) are existing UKAEA grabs to pick up miscellaneous waste and loose debris.

- x) Verigrip grab of GP01
- xi) Magnetic grab MG02
- xii) Magnetic grab MG03
- xiii) Magnetic grab MG04
- xiv) Magnetic grab MG05
- xv) Vacuum cleaner VC01

Basic Waste Box Furniture (Waste Routes)

It is of considerable importance to minimize the number of waste boxes, due to the cost of disposal and the environmental impact. Therefore, the PV & I waste needs to be closely

packed within the waste racks, yet allowing the grout to access any voids. To this end, a number of racks have been designed to receive different sections of the PV & I. Prime considerations during the design are:

- Minimize the number of racks and hence waste boxes.
- Commonality in design to reduce cost.
- Interface with the existing grabs and waste route.
- Racks are asymmetrically loaded to minimize the number of racks.
- Anti-flotation measures to stop insulation floating when grouting.
- Contain the asbestos through the waste route.

Due to the asymmetrical loading of the racks, it is proposed to modify the 8te hoist grab to cater for such loads.

CONCLUSION

The tests undertaken have confirmed that the pressure vessel and insulation sections can be cut and removed using an oxy-propane torch with iron powder injection or by a combination of disk cutting and oxy-propane without powder injection. Data collected relating to the amount of debris and dust produced, cutting speeds, quantities of consumables, temperatures reached and reliability of cut has proved invaluable. The chosen cutting method of oxy-propane with iron powder injection is flexible and reliable and, when combined with proven handling systems, has provided a practicable solution to a potentially difficult problem.

The strategy adopted and the work undertaken has helped develop a reliable design. Through making use of proven technologies and adapting existing equipment a cost effective and safe nuclear decommissioning solution has been reached.

Further tests are being planned using the production equipment in order to check interfaces, gain full confidence and to train site personnel before the actual decommissioning campaign commences.

In taking a controlled approach through development trials, holding regular risk and design reviews, in addition to HAZOP meetings, ENTECH have been able to maximize the technical data in the most cost effective way whilst constantly managing the project risks, leading to a successful outcome.