# MAGNOX ENCAPSULATION PLANT

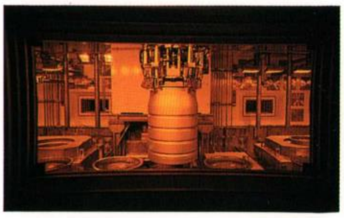

BNFL

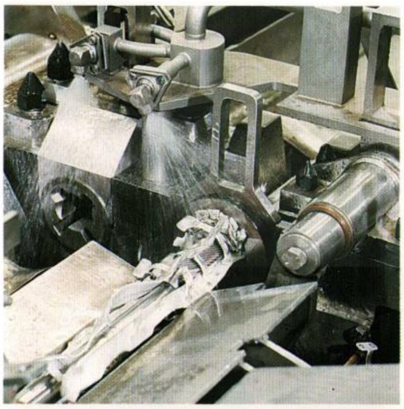
The safe and effective handling of nuclear waste is an issue of paramount importance to British Nuclear Fuels plc (BNFL).

BNFL has experience in handling all types of radioactive waste from high-level waste resulting from the recycling of fuel, to intermediate-level waste which comes from the first mechanical stage of reprocessing, and low-level waste which comes not only from the nuclear industry, but from hospitals and research establishments. BNFL's confidence in waste management stems from over 40 years' experience of nuclear fuel cycle services.

We are currently spending over £2 billion on a programme to improve waste handling at Sellafield. This investment will take BNFL into the 21st Century, safe in the knowledge that Sellafield is unrivalled for its waste management capabilities.

The Magnox Encapsulation Plant at Sellafield is a cornerstone of this waste management philosophy and its commissioning was a major milestone in the history of BNFL.





TOP Magnox cladding is removed in the Fuel Handling Plant.

ABOVE The cladding, or 'swarf', from Magnox fuel elements.

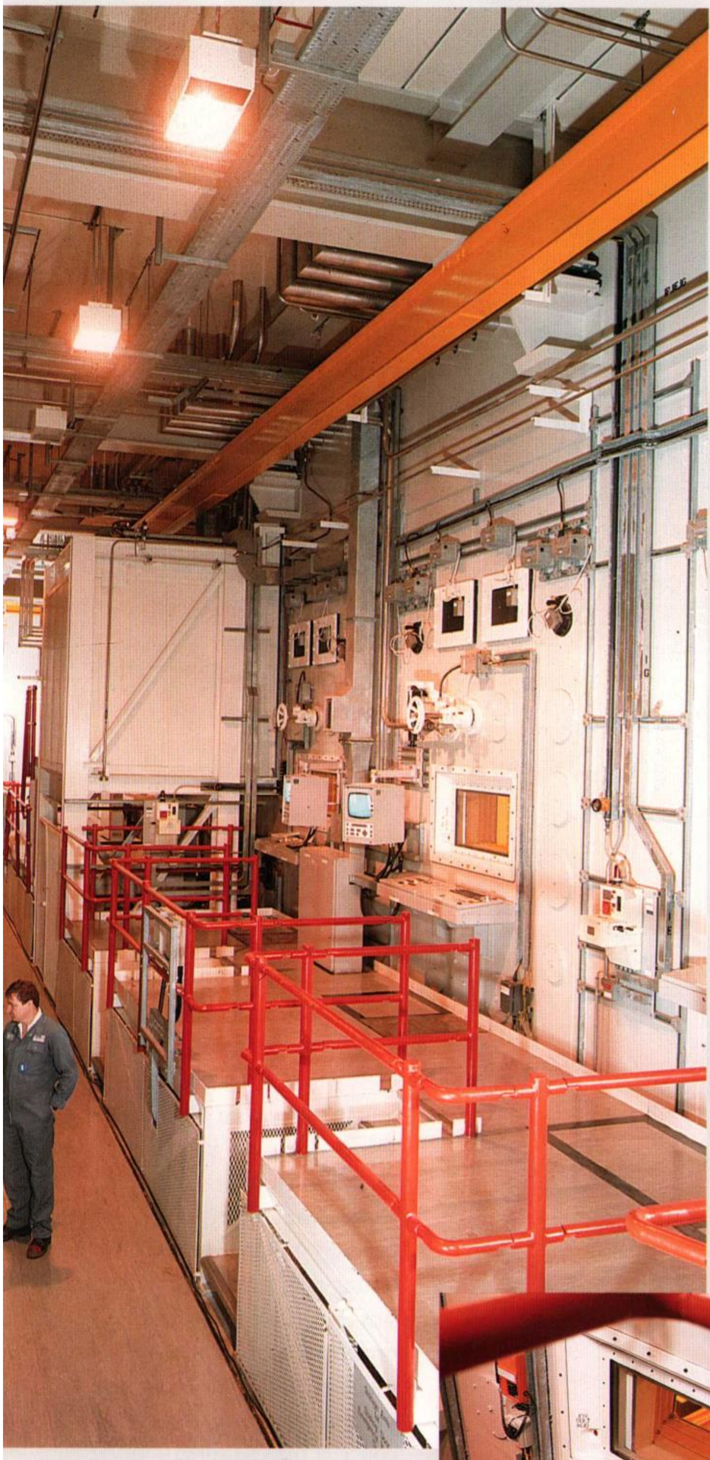
The plant, costing some £249 million, has been designed to process solid, intermediate-level radioactive waste, packaging it into a convenient form which provides for efficient and simple handling, transport, storage and eventual disposal.

The waste itself is made up primarily of the cladding or 'swarf' from fuel elements that have been used in Magnox nuclear power stations. Magnox stations were the first generation of nuclear power stations in Britain, deriving their name from the fuel they use – natural uranium metal enclosed in a magnesium alloy can.

The first industrial-scale nuclear power station in the world was the Magnox-fuelled Calder Hall, on the Sellafield site. Calder Hall was opened in 1956 by Her Majesty the Queen.

Each Magnox reactor contains over 8,000 fuel elements which provide energy for several years before they eventually become less efficient and are removed from the reactor for reprocessing at Sellafield. Reprocessing the fuel recovers valuable uranium and plutonium for re-use as fuel.

In order to be able to reprocess the Magnox fuel rod, its outer cladding must first be stripped off. By using specially designed remote control equipment, the cladding is peeled off into small pieces a few centimetres in length. Before the Magnox Encapsulation Plant was built, Magnox swarf was stored under water in purpose-built silos at Sellafield. Transport, storage and eventual disposal of the waste is eased, however, if a more manageable, consistent solid waste form can be produced. The plant has therefore been designed to encapsulate the waste within a cement grout matrix in stainless steel drums.



## THE PROCESS CELL

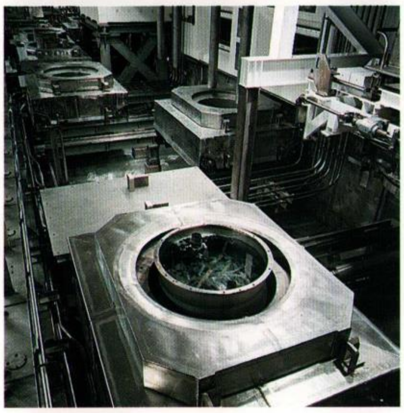
The encapsulation process takes place inside a heavily shielded concrete cell which ensures maximum operator protection from the radioactive swarf. BNFL's vast experience in cell design proved invaluable. Expertise and skills gained on other projects came to the fore, with the plant being completed to timescale and within budget.

All the in-cell equipment has been designed to operate remotely or automatically and to be as maintenance-free as possible, although items can be removed remotely should large-scale maintenance be necessary.

The cell has several process positions and 'posting-in' ports which allow the various items required to be loaded into it at the appropriate positions. Plant personnel supervise operations by way of lead-glass viewing windows and a number of television cameras placed at strategic points within the cell. Television monitors are positioned outside the cell near to operating positions, giving plant operators a choice of in-cell views.

TOP One of the operating faces.

ABOVE Operations within the cell are supervised by means of viewing windows and television monitors.



TOP The in-cell drum transporter picking up a drum.

ABOVE A waste drum is transferred by means of a bogie during inactive testing of the plant.

The waste drums are moved around within the cell by the In-Cell Drum Transporter (ICDT). Costing some £1.3 million, the transporter is in fact an advanced computer-controlled crane. A control system tracks all drum movements and ensures efficient use of the in-cell equipment. There are nine separate drum movements required in the cell, each of which has been allocated a priority. The most time-consuming operation is given the highest priority, so that a backlog of drums does not build up.

The transporter picks the drums up by means of four remotely-controlled 'fingers' which engage underneath the top flange of the drum.

There are two sets of lifting fingers – the first transfer the drum before it has been decontaminated. The second set handle the drum after decontamination. This ensures that clean, decontaminated drums are not touched by contaminated lifting equipment. Other drum transfers are carried out by special trolleys called 'transfer bogies' which manoeuvre drums across the cell between the transporter set-down positions and the process/posting positions.

The cell also has a power manipulator (a telescopic remote control arm) which can reach some parts of the cell not accessible by the In-Cell Drum Transporter. Essentially for maintenance work, the manipulator will remain in a parked position under normal operation.

Before the encapsulation process can take place, the plant must have the raw materials necessary. These are:

1 The waste itself – Magnox swarf is transported from the Fuel Handling Plant in a swarf container which is inside a swarf flask. The waste is covered with water at all times to prevent very small particles of uranium from drying out, as this could start a fire.

2 Initial grout to encapsulate the waste – a mixture of Ordinary Portland Cement, Blast Furnace Slag and water. The cement and blast furnace slag are delivered by road and loaded into silos. From here, they can be conveniently mixed in the correct proportions with water. Extensive testing of different grout mix designs was carried out to ensure the quantities used are correct. The mix is computer-controlled for consistency and accuracy. Slightly more concrete than required is mixed for

A swarf flask is moved into position.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each batch to allow samples to be taken and tested, and to stop air from entering the system as this could cause splashing of the concrete. The grout is mixed to tight quality assurance parameters.

3 Capping grout – a second type of grout, more fluid than that used for the initial filling. This second grout is a self-levelling mixture of cement, Pulverised Fuel Ash and water. The mix, like that of the initial grout, is computer-controlled and is the result of considerable testing to ensure that the correct quantities and concrete properties are obtained. The grout is pumped into the drum to form a seal over the encapsulated waste.

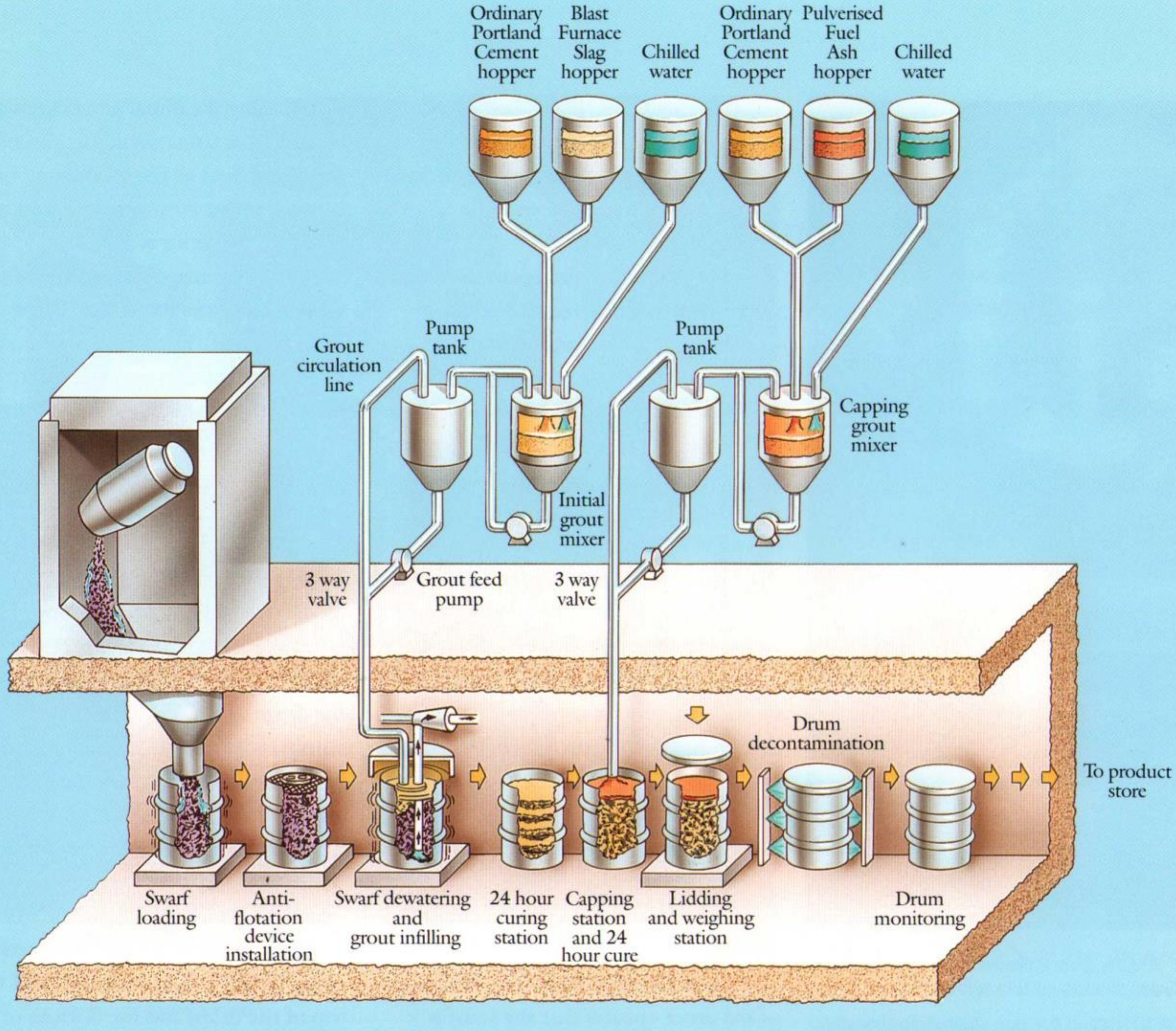

4 Drums – the high integrity stainless steel drums, specially designed by BNFL, are manufactured off the site to extremely high standards. The drum itself is made from 316L stainless steel and the lid is constructed from 304L stainless steel – both proven materials in radioactive environments. Every drum is checked before use to make sure it conforms to the rigorous standards required. Etched on to the outside of each drum is a unique number which allows thorough checks to be carried out including the exact material composition, manufacturer's name, date of manufacture – even the drum's eventual position in the on-site store. This detailed accountability means that the plant's operators have a bank of information about every drum in the cell.

TOP Raw materials for the grout are held in silos.

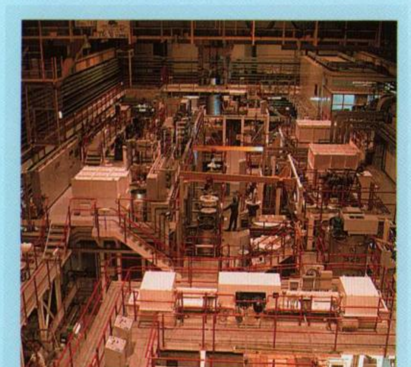
LEFT Development rig designed to simulate the processes involved in encapsulation.

ABOVE The specially designed stainless steel waste drums.

## THE PROCESS




A drum is lowered through the cell roof onto a waiting transporter bogie and moved to a position at the base of the swarf tipping chute. On the cell roof, a swarf flask is positioned on the tipping machine. At the tipping machine, an operator can remotely open the flask door to lower the swarf container holding the Magnox swarf and water. The container is tipped over to pour the swarf and water down the tipping chute



The cell roof area.

TOP A waste drum is posted into the cell from the roof area.

ABOVE The anti-flotation plate posting position.

and into the drum. The chute is then washed down to remove any traces of uranium and swarf. The empty container is refilled with water before being hoisted back into the swarf flask.

The drum containing the swarf and water is then transferred to a position underneath another posting station where an anti-flotation plate can be lowered into the cell and fitted inside the drum over the top of the swarf. The anti-flotation plate is a disc made from a steel mesh which stops the light swarf from floating in the cement grout and reduces the amount of splashing of grout during filling. The drum, containing swarf, water and an anti-flotation plate, is now moved to the heart of the process – the de-water and grout station where, in an inert atmosphere, water is removed from the drum. The inert atmosphere replaces the water and by excluding oxygen prevents uranium fires.

Once most of the water has been removed, the drum is vibrated whilst the initial grout is pumped in through a hole in the anti-flotation plate. The vibration of the drum ensures that the swarf is evenly distributed throughout the concrete grout. The grout is pumped through a pipe from outside the cell. To clean the pipe after grout transfer, a non-metallic device (known as a 'pig') is sent through the pipe to remove any traces of grout. The 'pig' falls into the drum and is encapsulated along with the waste. The drum is then transferred to the capping and curing area where it is left to allow the cement grout to set.

During the initial grouting, it is possible that some small particles of swarf may float to the surface and be exposed to the atmosphere. To counter this, capping grout is added.

The capping grout is a more fluid self-levelling concrete which covers any exposed swarf. There are ten stations able to perform the capping operation, preventing a backlog of drums from building up. Once again the pipe is cleaned by use of a 'pig' when the operation is complete.

The capping grout is left to cure for up to 24 hours before the drum is transferred to the lidding station. Here, a lid, complete with twelve specially made bolts, is posted into the cell and fitted to the drum. The lid is bolted on by 12 automatic nut runners which tighten the bolts to a pre-determined torque and in a set order so that stresses do not build up. The lid contains a specially designed filter which allows the small amounts of hydrogen generated during the storage of the drum to escape, without the release of any activity. It is important that the top of the drum and the bottom of the lid make an airtight seal.

ABOVE A total of ten capping grout stations prevent a backlog of drums from building up.

RIGHT The drum monitoring station.

Remotely operated tools are installed in the cell to ensure satisfactory lid seals.

After lidding, the drum is transferred to a decontamination chamber, where it is sprayed with high pressure water to remove any surface contamination. The drum is then monitored. Drum surfaces are automatically wiped and the swab samples are remotely withdrawn from the cell for monitoring.

Once monitored and confirmed as clean, the In-Cell Drum Transporter uses its clean set of fingers to place the drum in a special container called a stillage. The stillages, which each hold four drums, are posted into the cell to collect the encapsulated waste drums. Once full, the stillage is moved into a transfer area where it can be picked up and lowered through a shield door into the transfer tunnel that connects the plant to the Encapsulated Product Store.

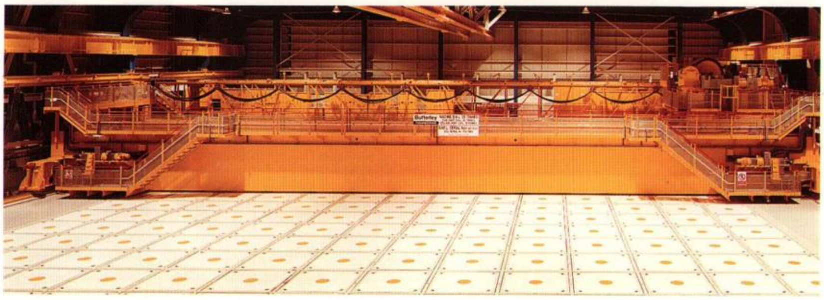
## THE STORE

The Encapsulated Product Store provides interim storage for intermediate-level waste pending disposal in a final repository. The store has a single storage vault with a capacity of some 12,500 drums. This capacity can be extended if necessary and the store has been designed with this in mind. Drums of encapsulated waste arrive four at a time in purpose-built stillages. The stillages are placed in channels by the computer-controlled store charge machine, and may be stacked up to 16 high. With 196 storage channels in all, arranged in a 14 by 14 horizontal array, this allows for the storage of over 3,000 stillages.

The store charge machine makes it possible to load or retrieve any stillage from any part of the store whilst its computer system carefully tracks and records all drum movements.

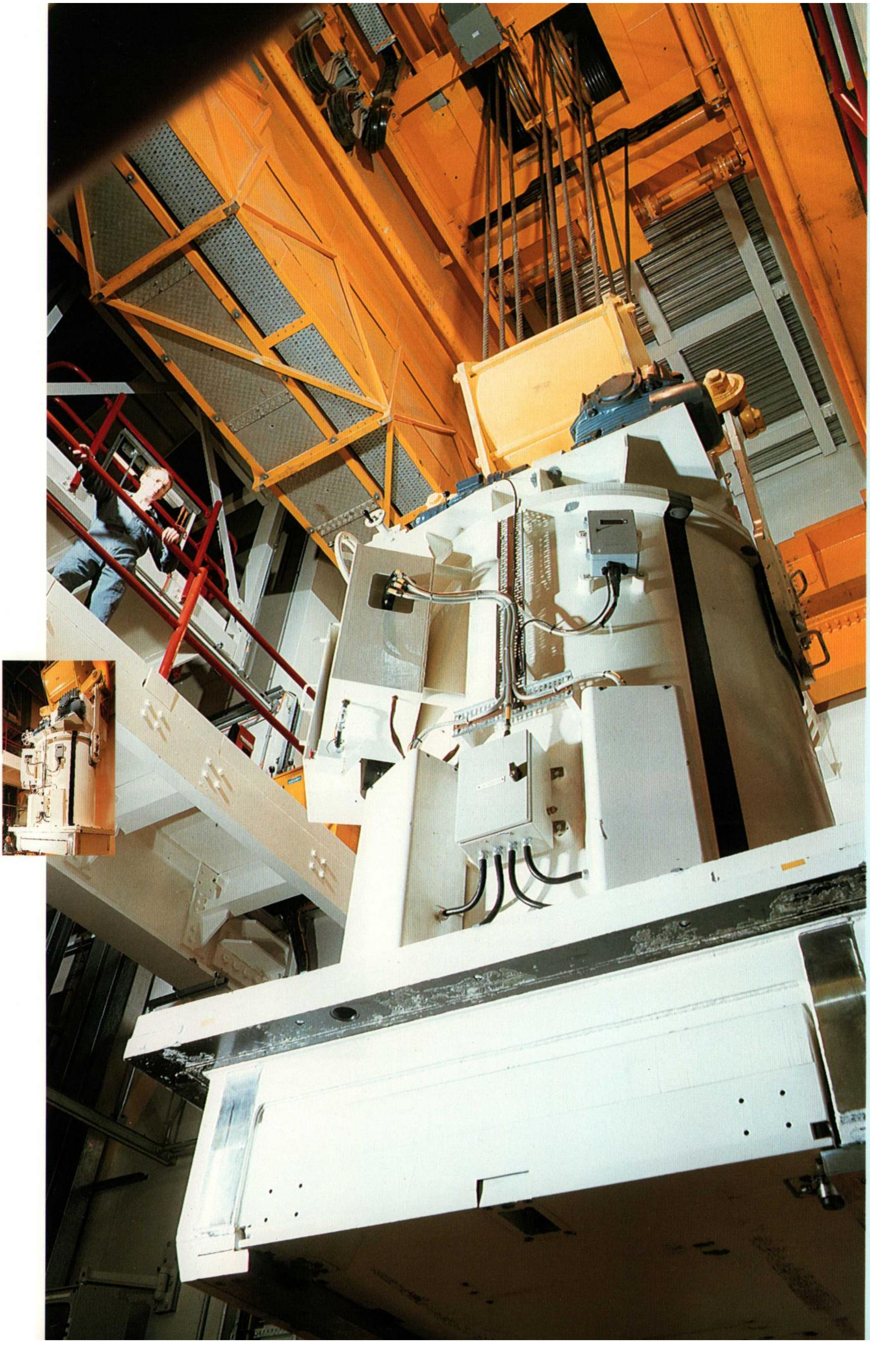
The store is cooled by a chilled air recirculation system to remove any heat given off from the drums.

A particular feature of the store is the single drum export facility. This allows drums to be removed in a suitable way for eventual disposal in an underground repository. This facility can also double as a way of taking drums into the cell.



The Encapsulated Product Store.

The single drum export facility which will enable drums to be removed for permanent disposal.



## MAGNOX ENCAPSULATION PLANT STATISTICS

Design work started in October 1984 which led to construction work starting just nine months later in July 1985. At its peak, the project employed 1,540 contractors on the construction of the plant.

Some 49,000 cubic metres of concrete were poured and over 20,000 tons of steelwork was erected. The length of cables in the plant–629,000 metres–would stretch from London to Leeds and back again.

Testing of the plant began in mid-1988, and after an extended operability trial and a period of final preparation it went active in July 1990.

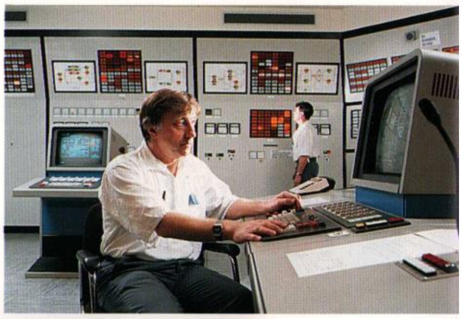
## THE MAGNOX ENCAPSULATION PLANT SERVICES BUILDING

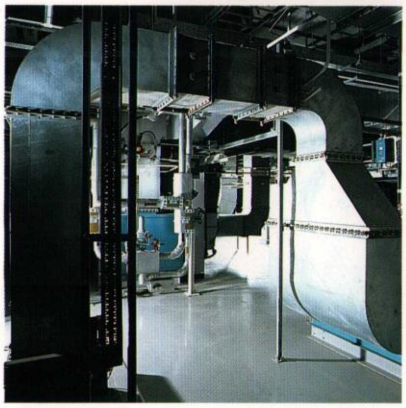
The four-storey services building provides all the necessary services to run the plant and cater for its personnel.

The offices within the building include the Management Control Centre from where operations within the plant can be monitored and controlled. Similarly, the Incident Control Centre houses a vast array of equipment to monitor all aspects of the plant in the unlikely event of an incident. Within the building, a maze of ducting and piping ensures a constant supply of ventilation air, process and domestic water, extract systems, heating and cooling, as well as an independent electrical supply.

The services building has been built to the same exacting standards as the plant itself and is seismically designed.

The effluent arising from the complex is transferred to other Sellafield facilities via the Effluent Transfer Facility.





TOP The incident control centre.

ABOVE Ventilation equipment in the plant room.

## MAJOR CONTRACTORS

BNFL Engineering was the prime project manager, co-ordinating all aspects of development, design, engineering, construction management, testing and commissioning.

Major contractors were:

### DESIGN CONTRACTORS

MECHANICAL
Costain Engineering Ltd.
Design Group Partnership
B&R Taylor
Kingham Knight
Davy McKee

CONTROL, ELECTRICAL AND INSTRUMENTATION
Costain Engineering Ltd.
B&R Taylor

### INSTALLATION CONTRACTORS

MECHANICAL/CIVIL
Sir Robert McAlpine
William Press
William Hare
Jordan Engineering Ltd.
Henry Hargreaves Ltd.
Strachan & Henshaw
Caxios Ltd.

CONTROL, ELECTRICAL AND INSTRUMENTATION
Matthew Hall
Hartford Instrumentation

### MANUFACTURING/SUPPLY CONTRACTORS

MECHANICAL
Beauford Engineers
James Bendal & Son
Henry Berry & Co. Ltd.
Peter Brotherhood Ltd.
BSC Cumbria Engineering
Costain Engineering
Duckinfield
Graham Engineering
GEC Energy
Lloyds British
Matterson
Markham.
Davy McKee Ltd.
McQuillan
Davy Morris
Motivair
NIS
Procor UK Ltd.
Strachan & Henshaw
Tangeant
Walker Fabrications
York International Ltd.

CONTROL, ELECTRICAL AND INSTRUMENTATION
Combustion Engineering
Hartford Instrumentation
Thurnall Engineering
Cardforth Controls
Allen West
Rees Instruments
Allen Bradley
AMELEC Instruments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