THE VITRIFICATION PLANT

BNFL

The inevitability of any industrial process is the production of waste – the nuclear industry is no exception. And like any toxic industrial waste, radioactive waste is extremely safe when properly managed.

At British Nuclear Fuels plc (BNFL), we have been managing the waste arising from the Company's operations for more than three decades.
Our £1.7 billion investment programme into new technologically advanced waste management plants will enable the Company to broaden this unrivalled experience even further.

By the turn of the century, Sellafield, BNFL's largest site, will be the location of a variety of fully operational waste management plants, designed individually by BNFL to deal with the full range of radioactive wastes.


High Level Waste Plants
H A Evaporation, Storage and Vitrification

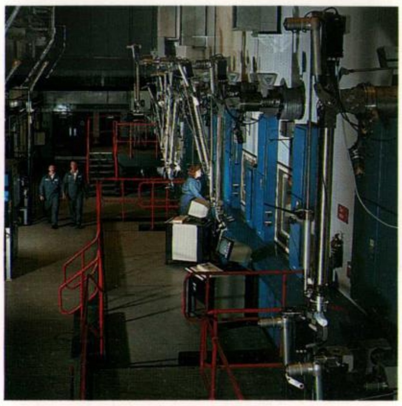
Waste from the nuclear industry basically falls into three distinct categories – low-level, intermediate-level and high-level waste and is produced in the form of solids, liquids or gases. As their titles suggest, each waste category emits varying intensities of radiation.

The most radioactive is high-level waste which arises from the reprocessing of irradiated nuclear fuel. At least 97% of irradiated fuel is recovered as reusable uranium and plutonium and the remaining 3% is high-level liquid waste.

Up to now, high-level liquid waste has been concentrated by evaporation and stored safely in double-walled stainless steel tanks, inside steel-lined concrete cells.

Although this method of storage has been demonstrated as safe and reliable for the last 30 years, and will continue to provide interim storage, it is now regarded as being costly, requiring maintenance over long periods of time, as well as leaving the waste in a liquid form.

A more suitable option is to convert the liquid waste into a solid form which is what the Vitrification Plant at Sellafield is designed to do. The start-up of operations in the £240 million plant,



The cell face of one of the vitrification lines.

which converts liquid waste into easier-to-manage glass blocks, marks the arrival of a new era in the treatment and management of high-level waste in Britain.

The process involved – vitrification – is considered internationally as the optimum method for converting high-level liquid waste into a solid form which can be stored safely, conveniently and economically, and which is suitable for eventual transport and disposal. In addition, vitrification reduces the volume of liquid waste to one third of its original volume.

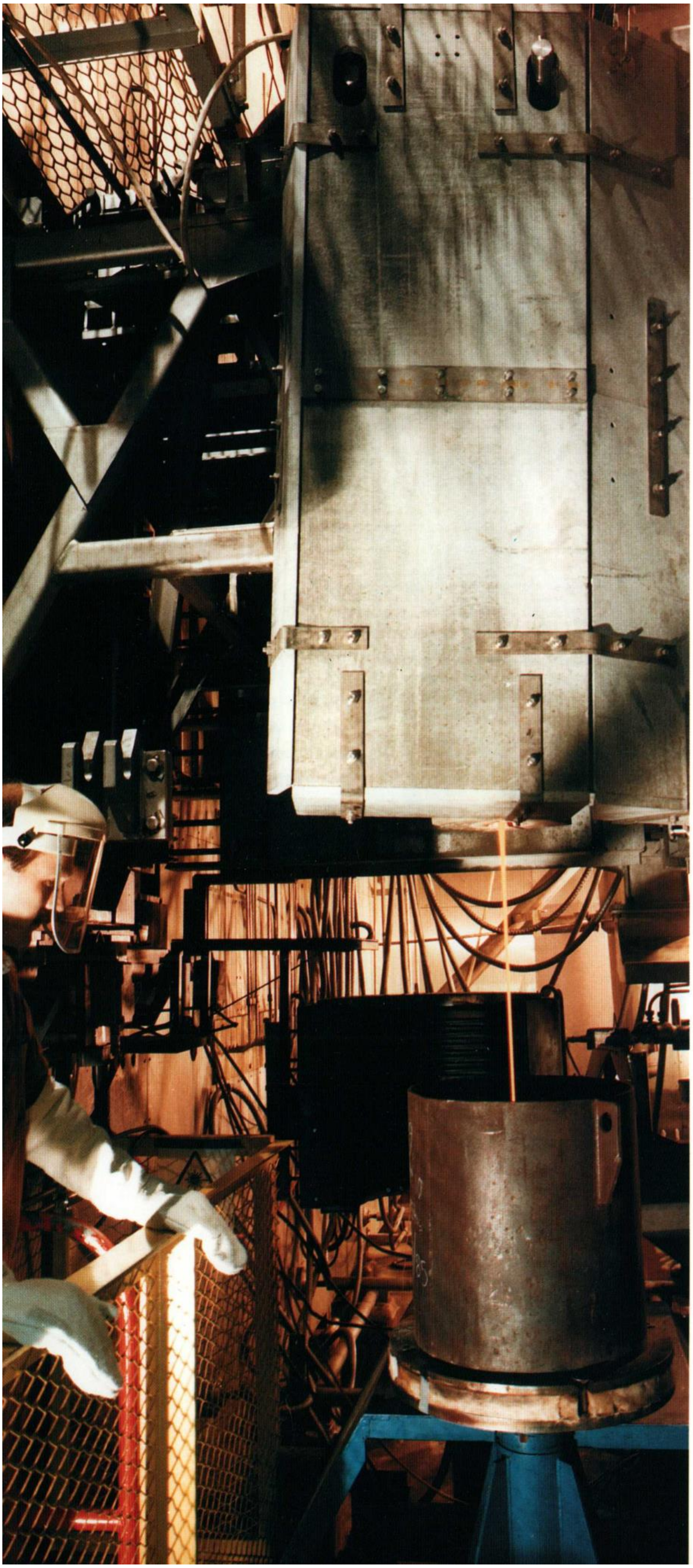
In the last 30 years, approximately 1,300 cubic metres of liquid waste has resulted from BNFL's reprocessing operations – equivalent to the volume of 12 double-decker buses. Vitrification will reduce this to the volume equivalent of four double-decker buses.

The Vitrification Plant will deal initially with liquid waste arising from the reprocessing of fuel from Britain's first generation of nuclear power stations – the Magnox reactors. In two years, the plant will start treating high-level waste resulting from the reprocessing of the more modern oxide reactor fuel in BNFL's new £1.85 billion Thermal Oxide Reprocessing Plant (THORP).

The Vitrification Plant is equipped with two separate production lines and each line has an annual capacity to vitrify the liquid waste arising from 2,500 tonnes of Magnox fuel, or 800 tonnes of Advanced Gas-cooled Reactor fuel, or 500 tonnes of fuel from Light Water Reactors.

All BNFL's contracts signed with overseas utilities since 1976 give the Company the right to return waste arising from reprocessing operations to its country of origin.

The full-scale pilot plant used to perfect the vitrification process.



VITRIFICATION – ITS DEVELOPMENT

Research and development into the vitrification process began in the late 1950s. In Britain, the feasibility of the HARVEST method – a one-step process – was demonstrated in a pilot plant using non-radioactive material.

Meanwhile, the French were developing the continuous vitrification process, and by 1978 had constructed a full-scale demonstration plant using radioactive material, Atelier de Vitrification de Marcoule (AVM). The plant demonstrated the process at industrial-scale and it was decided that adoption of the French continuous process would enable Britain to start operating a vitrification plant on a production scale at Sellafield, several years earlier than originally forecast.

Consequently, a contract was signed between BNFL and Société Générale pour les Techniques Nouvelles (SGN), who designed AVM, which involved SGN in the design of the Vitrification Plant.

A series of trials took place at Marcoule where the process proved to operate successfully with simulates of UK high-level liquid waste.

A similar full-scale facility was constructed at Sellafield. Although based on tried and tested French technology, thousands of hours of testing were conducted by BNFL to make the process suitable for British waste streams. The full-scale pilot plant was also used for training operatives and developing handling techniques. This experience was then transferred into the newly constructed Vitrification Plant for further commissioning work.

DESIGN, CONSTRUCTION AND TESTING

The go-ahead to build the Vitrification Plant presented BNFL's designers and engineers with unique design and construction challenges.

The main building structure – approximately 64 metres long by 38 metres wide by 40 metres high contains some 1,500 tonnes of structural steel, in addition to about 30,000 cubic metres of reinforced concrete.

In order to satisfy seismic and radiological requirements, an impressive 600 individual precast concrete units were delivered from off-site to construct the main cell areas of the plant.

After the concrete and the steel came the installation of an intricate maze of 40,000 metres of pipework, enough to stretch in a line from England to France. As the cells will be sealed for a planned lifetime of about 30 years, pipework services are duplicated, and even quadrupled in some areas.

Careful planning by an effective project management team combined with the latest computer-aided design techniques resulted in design and construction work going according to plan.

Orbital welding and an automatic bending machine, used at Sellafield on a very large scale for the first time, cut costs and speeded installation.

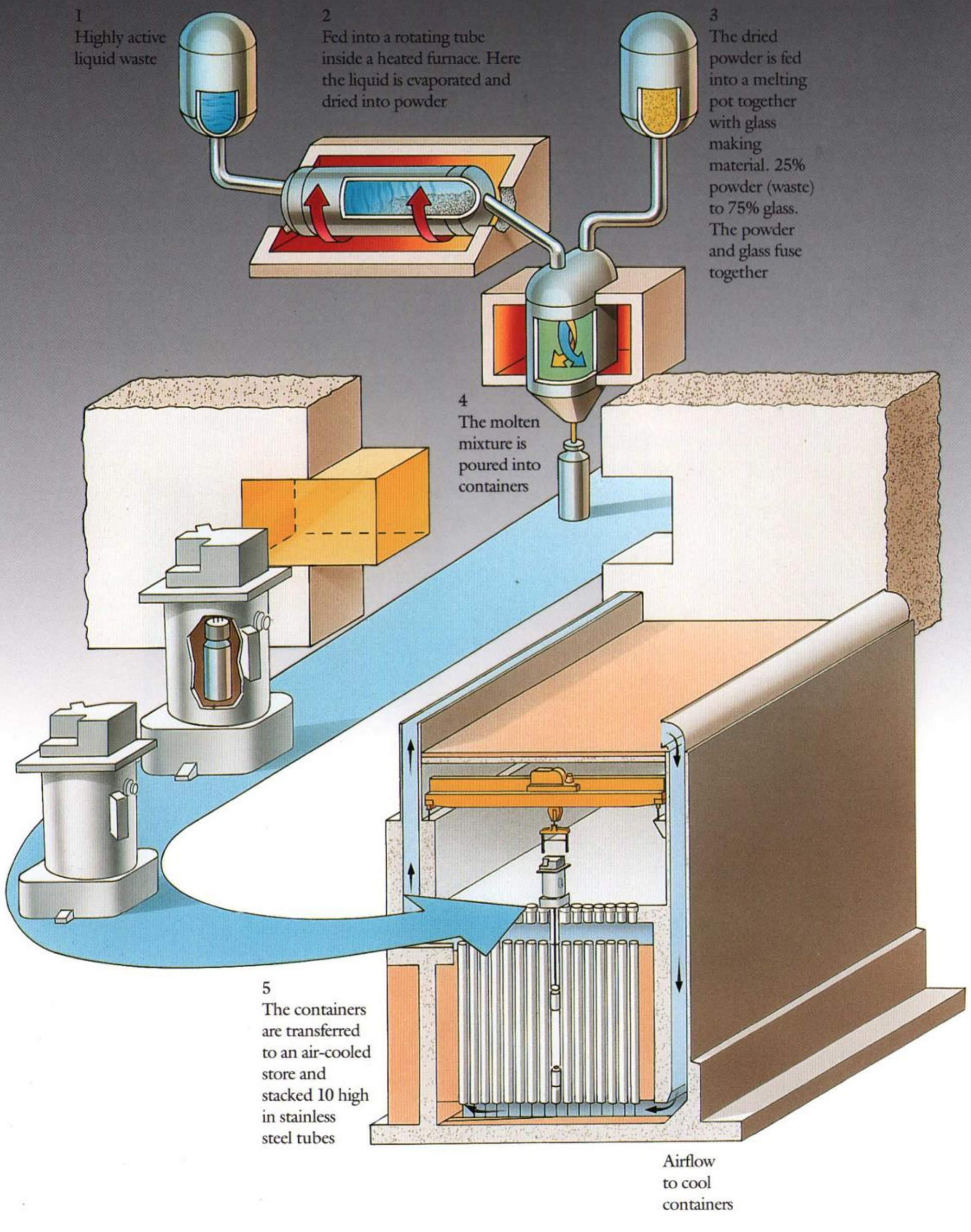
Once construction was complete, testing of the process began. This initially involved glassmaking using chemically simulated waste, and testing in-cell equipment under normal and abnormal conditions to demonstrate fully the safety of the plant. All in-cell equipment is designed and engineered to be remotely maintainable and replaceable. Every single piece of equipment was subjected to exhaustive testing including dismantling and reassembling of highly sophisticated equipment by remote control to ensure the safety and effectiveness of every conceivable form of operation under active conditions. Following more than 7,000 individual test schedules, the plant was ready to start full-scale production.

TOP The Vitrification Plant was designed using computer-aided engineering.

ABOVE Pipework in the plant would stretch in a line from England to France.

THE VITRIFICATION PROCESS

High-level liquid waste, currently in tank storage, is transferred via a pipebridge into the Vitrification Plant's highly active liquor tank. It then goes through the vitrification process which consists of the following stages.



CALCINATION

From the plant's highly active liquor cell, the liquid waste is metered continuously into the top end of the calciner – a stainless steel tube inclined at a 3% slope and rotated inside an electrically heated furnace. The liquid waste flows down the calciner and is successively evaporated, dried and partially denitrated, to produce a fine dry powder, known as calcine.

VITRIFICATION

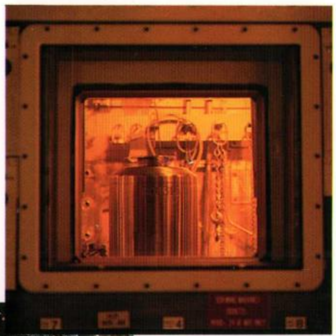
The calcine is mixed with crushed glass in a ratio of 25% waste to 75% glass inside the melting pot – an elliptical vessel heated to 1,150°C by an induction furnace. The glass melts and the calcine dissolves creating a molten mixture of glass and fission products–vitrified waste.

When the molten glass reaches a specific level inside the melting pot – usually after eight hours – it is poured into a product container situated beneath the melter.

PRODUCT CONTAINER HANDLING

The product container – approximately 42cm in diameter and 1.3 metres high – holds two pours from the melting pot, which amounts to about 400 kilogrammes of glass (150 litres).

Following the pouring stage, the container is lowered from the preheat furnace to a turntable where it is allowed to cool, and fitted with a lid and closed by an automatic fusion welding technique. The weld is checked before the container is moved to the decontamination area where high-pressure water jets remove loose surface contamination. The container is then inspected remotely before being transferred inside a shielded flask to the Vitrified Product Store.



ABOVE A cell where product containers are filled, cooled and fitted with a lid.

RIGHT Product containers are transported to the Vitrified Product Store inside high-integrity product flasks.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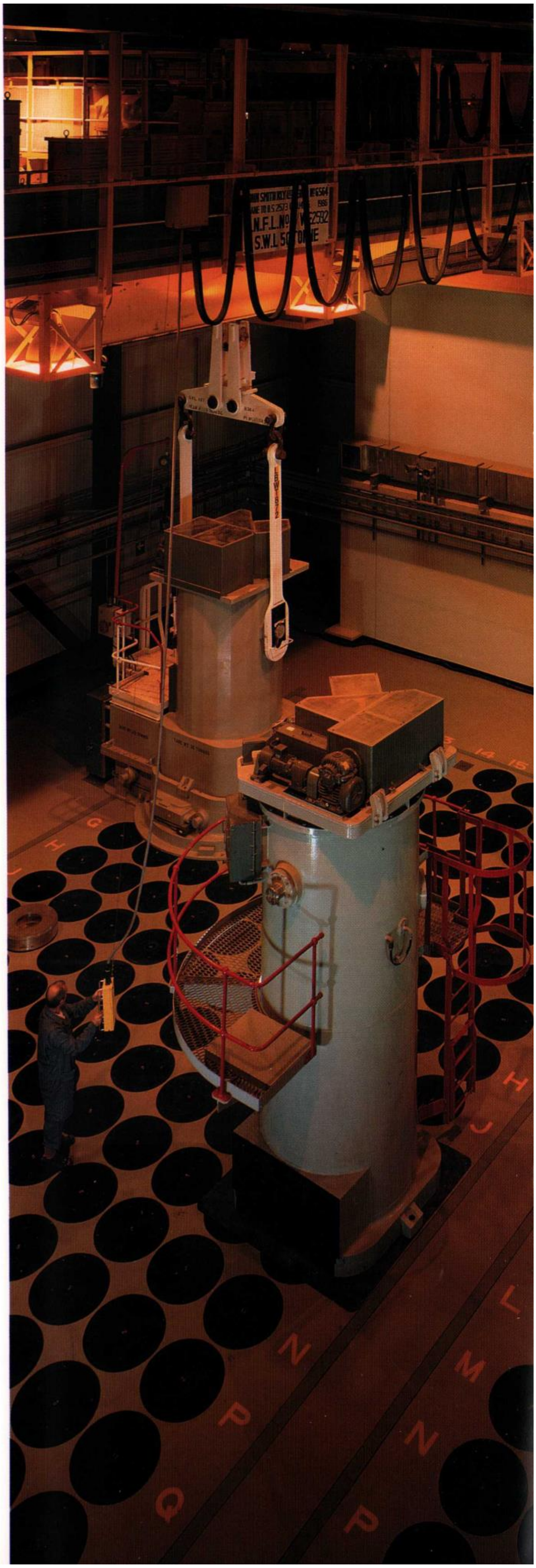
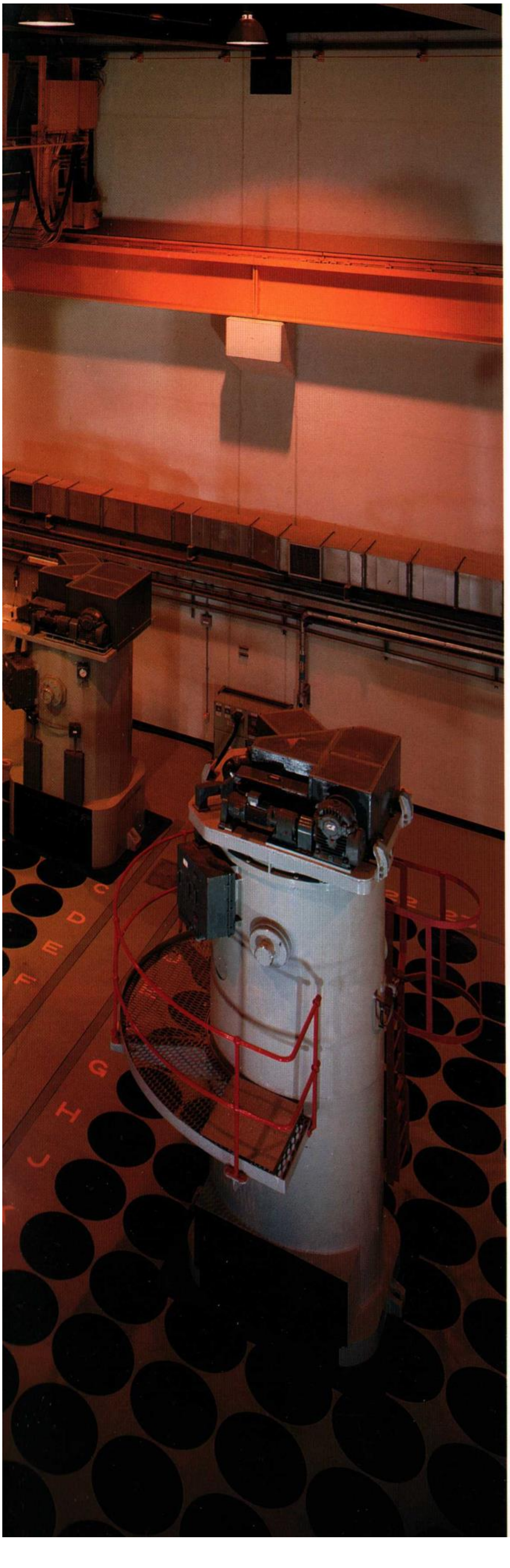
THE VITRIFIED PRODUCT STORE

The filled product containers are air cooled by natural convection in the Vitrified Product Store, adjacent to the main Vitrification Plant. The store consists of a series of rectangular compartments constructed on a base slab of reinforced concrete. Inside each compartment is a storage channel and thimble tube, sealed at the bottom, which accommodates containers stacked 10 high. The entire store has the capacity to store up to 8,000 containers in total. A natural airflow removes heat from the outer surface of each thimble tube. As there is no contact between the air and the radioactive materials in the store, no filtration is required before the air is discharged.

The compartmental design of the store will enable sections to be added for future expansion. Containers of vitrified waste will remain in the store for up to 50 years.

Vitrified Product Store control room.





Positioning a product flask
over a storage channel.

PLANT LAYOUT

The Vitrification Plant has been designed as a number of cells where the high-level waste is handled and processed. Some of the cells are common to two independent vitrification lines and others are specific to each line.

The main cells are:

Highly Active Waste Receipt and Storage.

Vitrification, containing the calciner, melter, dust scrubber and condenser.

Decontamination of containers.

Control Cell where containers are monitored for external contamination.

Breakdown Cell providing facilities for remote maintenance of equipment, dismantling, activity monitoring, cutting and packaging of obsolete equipment.

In addition, the plant has a series of building services such as active ventilation systems which are of a standard design incorporating filtration and extract fans suitably reinforced with stand-by capacity and alternative supplies where appropriate.

Particular attention has also been paid to the design of such facilities as sampling equipment, instrumentation, ventilation filters etc, to ensure that the designs meet fully radiation dose constraints.

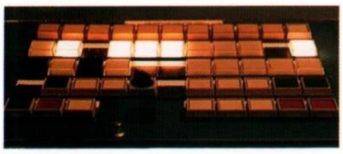
Operations from a highly sophisticated main control room activate and monitor the plant's output. And in addition to the main plant areas, an administrative centre provides office accommodation, restaurant, change-rooms and general facilities to support the operation of the plant.

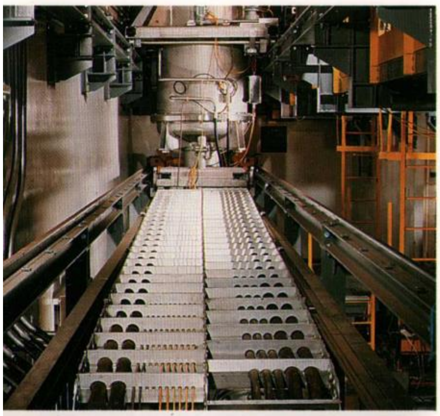
ABOVE Workers at the operating face of the control cell.

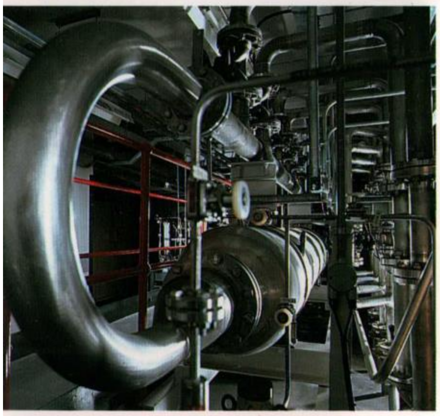
TOP RIGHT The area where vitrified product containers are washed before storage.

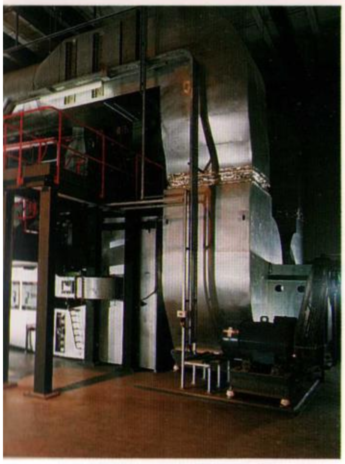
CENTRE Cooling water monitoring room.

RIGHT Stand-by cooling fans and filters.









HEALTH AND SAFETY

Safety figured foremost in the minds of BNFL's engineers when the Vitrification Plant was designed and built. Every stage of design and construction was overseen by independent nuclear inspectors. Such close scrutiny will continue throughout the plant's operational lifetime. The plant will be operated to meet the conditions of Sellafield's site licence issued by the Nuclear Installations Inspectorate. Any radiation doses to members of the public and employees must be kept as low as reasonably achievable and within internationally accepted limits.

Within the plant, all working practices involving radioactive materials are strictly controlled. For example, there are set limits on the quantity of radioactive material allowed in any one area and on the sizes of containers used. The pressure inside many of the plant's working areas is less than that outside so that if a leak should occur, air is drawn into the radioactive area rather than the other way round.

Safe working procedures and an extensive workplace monitoring programme ensure the safety of the plant's workforce. The plant is equipped with sensitive detection and alarm systems to give immediate warning of a radiological incident. Appropriate evacuation and emergency procedures have also been tailor-made for the plant.

Workers carry out in-cell operations, such as maintenance work, shielded behind thick concrete and lead walls fitted with lead-glass windows more than a metre thick. Operatives use remotely controlled dexterous equipment, often with the aid of closed-circuit television within the cell.

Workers are protected from in-cell operations by thick concrete and lead walls fitted with lead-glass windows.

Working areas are constantly monitored and access to areas where there is a risk of contamination above a set limit is through controlled barriers located in changerooms where everyone must change into factory issued clothing and shoes. In addition, workers must wear monitoring instruments such as film badges to assess the external radiation dose. All workers monitor themselves thoroughly before leaving a radioactive area.

BNFL also protects employees from potential hazards common to many industrial processes such as handling chemicals, maintenance of machinery, use of machine shop equipment and electrical work. Safety is ensured primarily by the design and construction of plant and by the procedures for its operation, maintenance and, where appropriate, modification.

ABOVE Employees monitor themselves in one of the purpose-built changerooms after working in the plant.

RIGHT Health physics workers carry out routine monitoring of the plant.

Discharges of low-level liquid and gaseous waste to the environment are authorised by the Department of the Environment and the Ministry of Agriculture, Fisheries and Food, various limits and conditions being imposed to protect the environment.

BNFL monitors radioactive discharges regularly and takes thousands of environmental samples a year to ensure that radiation levels remain well within the authorisations. The authorising departments also carry out their own environmental sampling programmes.

The Vitrification Plant will be operated to satisfy fully the highest scrutiny of both BNFL and Government inspectors. The opening of the plant is a significant achievement for BNFL and a reflection of the Company's commitment to an in-depth waste management programme.

MAIN CONTRACTORS

VITRIFICATION PLANT

DESIGN CONTRACTORS
Société Générale pour les Techniques Nouvelles (SGN)
Simon-Carves Ltd
Design Group Partnership

CONTRACTORS ON SITE
Norwest Holst Civil Engineering Limited
William Hare & Co. Ltd
Matthew Hall & Co. Ltd
Laing Industrial Engineering & Construction Limited
Hayden Young Limited
Babcock Power Limited

MECHANICAL PLANT
Alldays, Peacock & Co. Ltd
Amada Techni-Scia SA
APV International Ltd
Barr & Stroud Ltd
Beauford Engineers Ltd
Henry Berry & Co. Ltd
Peter Brotherhood plc
Capper Neill Plastics Ltd
Cumbria Engineering Ltd
Darchem Projects Ltd
Engart Fans Ltd
GEC Energy Systems Ltd
GEC Turbine Generators Ltd
Graham Engineering Ltd
C P Hobal Ltd
Hick Hargreaves & Co. Ltd
Keighley Lifts Ltd
D D Lamson Ltd
Herbert Morris Ltd
NEI – Nuclear Plant Services Limited
NEI – Thompson Nuclear Engineering
Société Générale pour les Techniques Nouvelles (SGN)
Steels Engineering Ltd
Strachan & Henshaw Ltd
VNE (Nuclear) Ltd
Westinghouse Systems Ltd
Xomox Ltd

ELECTRICAL AND INSTRUMENTATION
Bonar Long Ltd
Chloride Power Electronics
Fisher Controls Ltd
Gould Electronics
Hartford Instrumentation Ltd
Instem Computer Systems Ltd
Kent Process Control Ltd
Nuclear Enterprises Ltd
Rees Instruments Ltd
Unibit Holdings Ltd

STAINLESS STEEL MATERIALS
British Steel Corporation
TI Stainless Tubes Limited
Sandvik Steel (UK)

VITRIFIED PRODUCT STORE

Eden Construction Limited
William Hare & Co. Ltd
Haden Young Ltd
Matthew Hall & Co. Ltd

MECHANICAL PLANT
Byard Kenwest Engineering Ltd
Darchem Projects Ltd
Graham Engineering Ltd
C P Hobal Ltd
McQuillan Engineering Co. Ltd
John Smith (Keighley) Ltd

ELECTRICAL AND INSTRUMENTATION
Field & Grant Ltd
Kent Process Control Ltd
Automation Systems
NEI Electronics Ltd
Rees Instruments Ltd

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