

BERKELEY VAULT DECOMMISSIONING – IN A COMMERCIAL ENVIRONMENT

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ABSTRACT

BNFL Magnox Generation are currently undertaking a project to completely decommission Berkeley Power Station Active Waste Vaults and safely package all the remaining wastes on site until the NIREX repository becomes available. A multi-disciplinary team managed by NUKEM NUKLEAR GmbH has been awarded a contract to decommission the Active Waste Vaults. This contract covers the project management, design, build, operation and removal of the temporary facilities required to extract, package and place the wastes into safe storage, including the preparation of the safety case.

The heavily shielded facilities and remotely operated equipment required to handle and process the wastes are described, and the design solution indicates how various novel problems have been tackled.

The nuclear industry world-wide is now keenly interested in the costs of decommissioning plant at the end of its operational life. This project gives an approach to managing these costs in a practical commercial manner.

INTRODUCTION

Over their operational life, which began in 1962 and continued until 1989, the two MAGNOX gas-cooled reactors located at Berkeley, Gloucester, England generated over 40 billion units of electricity. The station ran at 300 MW power output, and was the first commercially operating nuclear station to be decommissioned in the United Kingdom. The site is currently the responsibility of BNFL Magnox Generation.

The units have been defuelled, and as much plant and equipment as possible removed. They now remain under a long-term care and maintenance regime to permit decay of the core activity, prior to final dismantling.

During operation of the reactors radioactive wastes arising both from the power station and from the adjacent Berkeley Technology Centre accumulated in the Active Waste Vaults. The waste is largely Intermediate Level Waste (ILW) and Low Level Waste (LLW) and consists of solids and mobile wastes (materials that cannot be grouted without intimate mixing, i.e. sludge and resins).

The material residing in the Vaults is the last significant radioactive inventory, with the exception of the reactors, and is to be retrieved, processed and conditioned in a new process facility, and placed into safe storage.

BNFL Magnox Generation carried out an extensive series of studies and investigations into how the Vaults might be cleared. Following on from this, in 1995, a two stage tendering process was initiated to select a suitably capable contractor to carry out the work under fixed price contract conditions. The enquiry documents emphasised the requirement for the contractor to perform the task, without prescribing the details, and tenderers were free to propose their own technical solution having been provided with the study data for information only. After an initial response from the market, Magnox invited and partly funded three companies to produce best and final offers. The contract was finally awarded in April 1996 to NUKEM Nuklear GmbH with a sub-contractor team comprising its UK subsidiary NUKEM Nuclear Ltd, W.S.Atkins and AMEC.

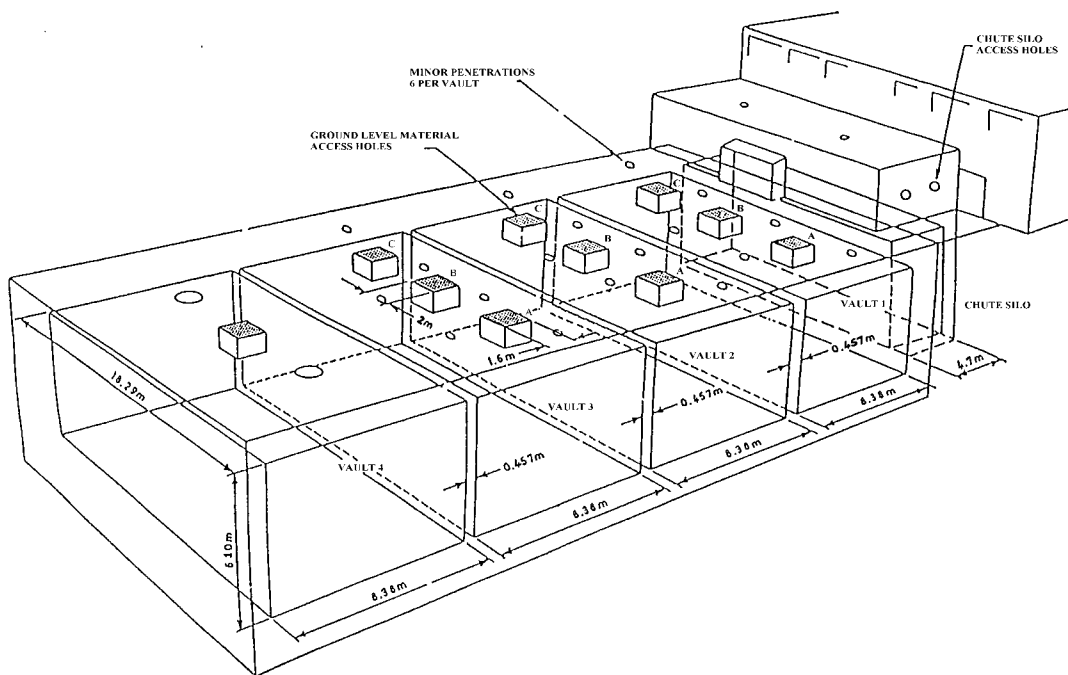


FIGURE 1 WASTE VAULT AND CHUTE SILO ARRANGEMENTS

THE DECOMMISSIONING TASK

Overall Objective

The contract end state is achieved when all wastes have been removed, processed and placed into storage, the Vaults have been decontaminated and all temporary plant and facilities cleared from site with the Final Report accepted by BNFL Magnox Generation and the Regulators. (The temporary plant includes the retrieval and process buildings and equipment.)

The task is to encompass all activities, documentation and labour necessary including the writing of the safety case, to retrieve all the waste from the existing Vaults. (BNFL Magnox Generation must approve the safety case and retain the responsibility for obtaining safety case

approvals and for obtaining the Letter of Comfort for the waste-forms). The ILW is then to be sorted, packaged and stored to modern standards, with LLW solid waste drummed for disposal at the Drigg site.

To accomplish this the retrieved waste has to be segregated into streams of solid and mobile waste, ILW and LLW. The solid ILW waste is to be encapsulated in a grout and placed in NIREX 3m³ boxes, or 500 litre drums in the case of the Berkeley Technology Centre Fuel Element Debris (FED). The mobile waste has to be extracted from its containers, treated and pumped into storage tanks for interim storage. This storage facility will use the mainly redundant Caesium Removal Plant (CRP), appropriately modified. Waste liquors have to be treated and disposed of via the existing Active Effluent Treatment Plant (AETP). BNFL Magnox Generation, as part of the overall project, are to process and package the mobile wastes using their existing transportable encapsulation facilities which have a programme of use at other sites.

The encapsulated LLW will be sent to Drigg and the ILW stored along with the grouted boxes and drums in a purpose built box and drum store.

Vault and Waste Description

The five reinforced concrete boxes, which form the Active Waste Vaults, are illustrated in Figure 1. Vault 4 previously contained drummed ILW wastes, but these were removed prior to defuelling and the Vault is now empty. Vault 3 contains canned sludges, and canned miscellaneous contaminated items. Vault 2 contains station FED. Vault 1 contains station FED, Berkeley Technology Centre FED and drummed ion exchange resins. The Chute Silo contains mostly control rods together with a small number of charge chutes.

The approximate internal dimensions of the Vaults are 18.3 m long by 6.4 m high by 6.4 m wide. The Vault ceiling is 1.8 m thick, the concrete external reinforced concrete walls are approximately 0.9 m thick, and the internal partition walls are approximately 0.5 m thick. The Vaults are below ground level, with three vertical discharge openings located in each Vault roof providing access. The Chute Silo internal dimensions are approximately 14.9 m long by 6.4 m high by 4.7 m wide. It protrudes above ground to incorporate the horizontal access openings and extends to a height of 2.7 m above the other Vaults. A 305 mm thick stone chippings gravel bed covers the floor in Vaults 1,2,3 and the Chute Silo to aid drainage and to protect the Vault floor from the impact of heavy waste items.

A record of individual entries to the Vaults has been kept and a waste inventory report produced. Further confirmation of the Vault contents has been obtained from an in-Vault video survey. The waste to be retrieved comprises a mixture of miscellaneous items, summarised in the table below. The total volume is approximately 1900 m³. It includes power station FED which was discharged loose and consists mainly of graphite and Magnox with some Zircalloy and stainless steel, canned power station sludge and resins, and canned Miscellaneous Contaminated Items (MCI)

| <i>Vaults 1,2,3</i> | <i>Chute Silo</i> |
|---|--|
| 1000m ³ Fuel Element Debris (FED) 150m ³ canned Sludges and Resins Canned Miscellaneous Contaminated Items (MCI) –6050 individual items–paint tins, long liners, black can liners, red cans, sludge cans, black cans and 45 gallon drums | 78 control rods 4 charge chutes 1 trailing lead thermocouple chute |
| Mainly ILW dose rates up to 6500 mS/hr 160 m ³ of Vault floor gravel chippings Weight from a few kilograms up to 203 kg for the 45-gallon drums (ex Chute Silo items) | |

In addition there is a miscellany of long heavy activated items from the reactor stored in the Chute Silo. The charge chutes are the largest objects in the Vaults, with a weight of 1780 kg and measuring 12 m long, 300 mm diameter. Some waste containers have suffered damage by the impact of wastes falling onto the waste pile during loading. The Vaults are not waterproof and there has been measurable water ingress from the roof shutter mechanisms, which has led to degradation of some of the wastes and waste containers.

The radionuclide content of the wastes has been assessed from the results of sampling and from the results of in-Vault gamma spectroscopy, combined with the dose records made when the waste was posted. In 1990 measurements of activity were taken which showed contact dose rates varying between 160 and 6500 mSv/hr. The predominant isotopes measured were Co⁶⁰ and Cs¹³⁷. The radioactive content of the waste depends on the exact origin of the material and the length of radioactive decay that has occurred.

Work Programme

The work has been divided into six phases.

| | |
|---------|--|
| Phase 1 | Complete investigations, surveys, design and safety case including assessment by BNFL Magnox Generation and assessors. |
| Phase 2 | Manufacture and site construction |
| Phase 3 | Non-active commissioning |
| Phase 4 | Active commissioning |
| Phase 5 | Operation of the plants to retrieve, process and store the waste. |
| Phase 6 | Decontamination, site clearance including removal of temporary facilities and preparation of Final Report. |

Each Phase is a contractual Milestone, with penalty clauses attached to each Phase.

The project started in April 1996 and the planned completion date was the end of September 2002.

Progress at November 1988 is described in Section 9.

PROJECT MANAGEMENT STRATEGY

Traditionally in the U.K. nuclear industry the Client has specified the design, invited construction and equipment tenders and has been responsible for writing the safety case, and finally operating the facilities. In this case the overall direction, project management and risk lay with the Client. However in order to quantify the costs and minimise their risk, BNFL Magnox Generation decided to place greater emphasis on the Contractor, who would be required to handle as much as was practicable of the entire task. This strategy provides the nuclear industry with an approach to demonstrate economic competitiveness with other energy providers.

It was evident that a range of expertise was required to tackle this demanding project. In response to the tender enquiry, NUKEM put together a team with complimentary skills. NUKEM Nuklear GmbH had considerable in house expertise in the project management and design of nuclear waste handling facilities for eastern European Clients, and through their U.K. subsidiary, NUKEM Nuclear Ltd, detailed engineering and practical decommissioning skills including Health Physics services. W. S. Atkins provided complimentary skills in civil and mechanical design and in safety case expertise, Amec Construction provided the civil engineering construction capability. In this manner a very powerful international team was assembled with wide engineering project management, design, construction and decommissioning operating experience.

The strategy adopted was to look for low cost solutions and proven techniques wherever possible and work packages, roles and responsibilities were agreed. Project management arrangements that were put in place include fixed price contracts for team members, with the exception of civil construction. This is contracted on the basis of an agreed target price under the terms of the New Engineering Contract. Amec had liaised closely with the designers prior to letting this package and had advised on best construction practise. All subcontracts for equipment and services have or will be placed following competitive tender on a fixed price basis.

Project cost control is vital and starts with the design. Equipment and facility designs take account of the fact that the required operating life of the plant is only a few years, and much existing site equipment has been utilised. Particular attention has been given to interfaces between parties, to make sure that everyone is clear where work package deliverables start and end. Regular co-ordination meetings are held and quality controls ensure that interfacing parties “sign on” to team members’ deliverables.

TECHNIQUE

The solution adopted in the first stage of bidding envisaged access to the waste by way of the empty Vault 4, entering and emptying each Vault sequentially through the Vault’s sidewalls. The ILW solid waste store was to be constructed in the emptied fuel storage pond. BNFL Magnox Generation amended the specification prior to the second round of bidding to stipulate that it must be possible to access and retrieve waste from any Vault at any time and excluded use of the pond.

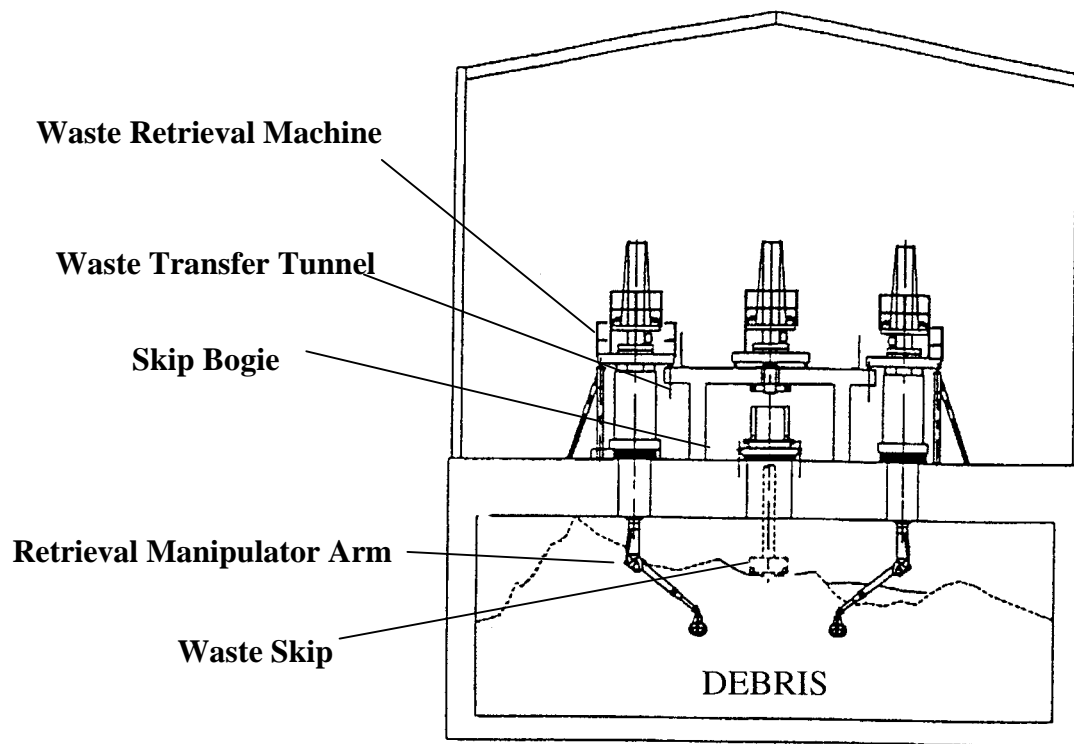


FIG 2 RETRIEVAL SYSTEM

Fig (2) shows the actual solution. Fig (3) gives the waste handling flow. A retrieval facility, including a shielded transfer route, is constructed over the Active Waste Vaults. Additional penetrations cut through the tops of the Vaults allow the insertion of a 1.5te capacity recovery skip and remotely operated heavy-duty manipulators such that waste can be recovered (by grabs) from any part of the Vault and placed in the recovery skip. The manipulator penetrations are 0.9 m diameter, four per Vault, and the centrally positioned skip mast aperture is 1.7 m by 3.2 m, one per Vault. These openings are provided with shielded door covers. Skips are filled in the Vault, raised and placed onto a transfer bogie running inside a shielded transfer tunnel constructed over the Vaults. Waste is then moved to the end of the route and either transferred to a shielded overpack to permit onward transfer to the processing facility or placed in temporary buffer storage. Vault 4 is used to provide the buffer store, to allow any initial pre-sorting that may be required to ensure a continuous flow of material to the processing facility. Closed circuit television provides a view for operators located in a remote control room.

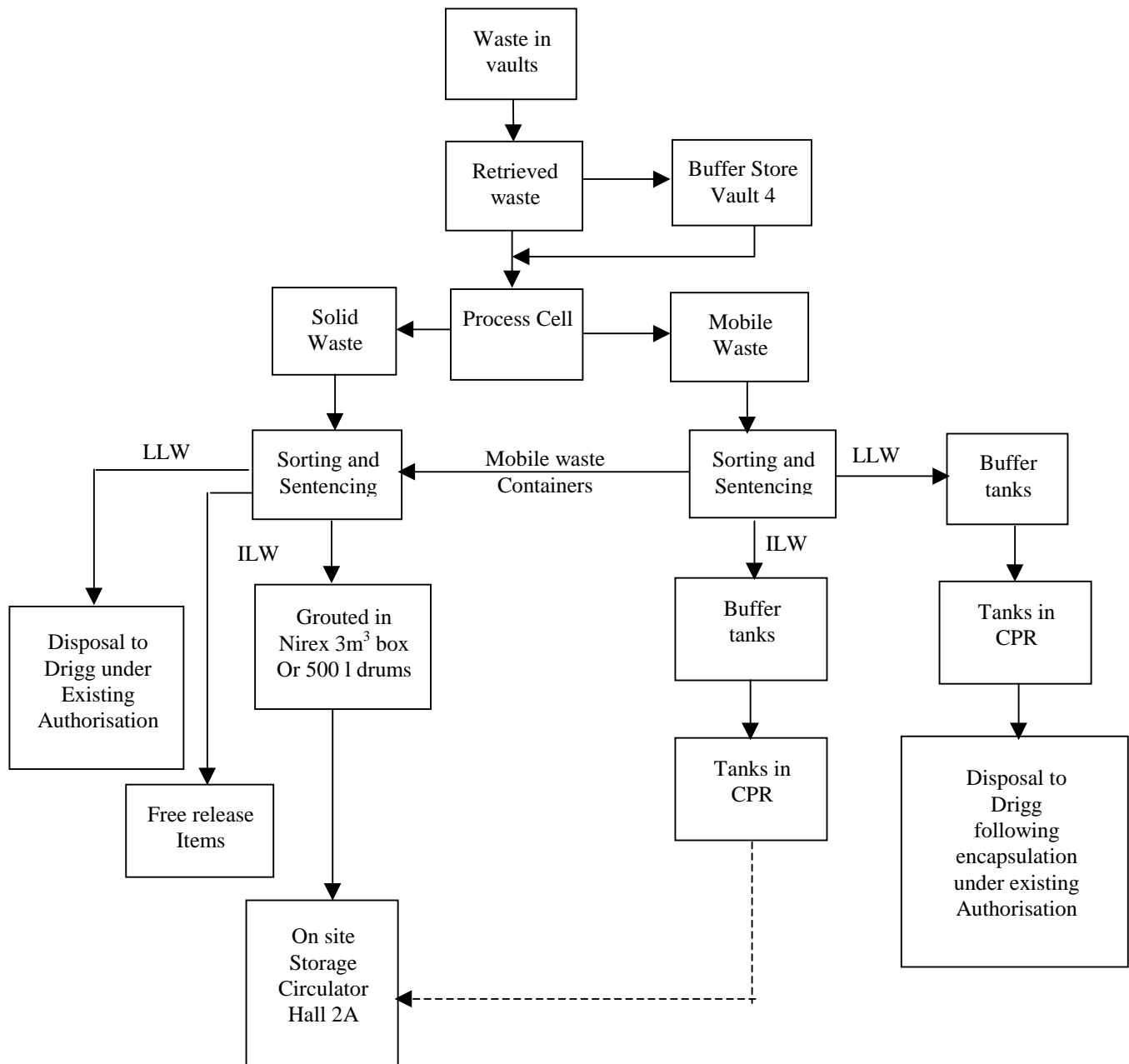


FIG 3 WASTE HANDLING FLOW DIAGRAM

Once within the overpack, the skip is transferred to the processing facility over site roads using a purpose built trailer towed by a tug.

A shielded facility for handling and sorting retrieved wastes has been constructed in an existing building, previously used for decontamination works. This facility contains arrangements for handling both solids wastes, principally FED, and mobile wastes extracted from containers.

The shielded overpack docks with the input shield door and the skip is transferred into the cell by a roller conveyor, emptied and returned to the overpack. Processed ILW solid waste is transported in a second overpack to the ILW store leaving the cell by similar means in either a NIREX 3m³ grouted box or in a 500 litre drum packed four to a stillage. The modified CRP receives and stores mobile waste pumped via an existing line.

WASTE RETRIEVAL SYSTEM

Retrieval Manipulators

It was decided to develop a telescoping mast manipulator system, after careful consideration. (Previous studies BNFL Magnox Generating Division had demonstrated the feasibility of using a remote-roving vehicle to gather waste, but deploying the vehicle onto a mountainous waste pile was judged to be too risky). A modified proprietary industrial arm commonly used for vehicular mechanical handling forms the basis of the design of the Vault end of the manipulator. Full coverage requires four access points per Vault due to the reach limitations. The waste route out requires an additional central penetration through which a skip is introduced and removed when filled.

Two machines are provided. The nominally 920 mm diameter access holes are stitch-drilled through the roof. A sliding shutter is fitted to each of the openings, which provides replacement shielding where the concrete of the Vault roof has been removed. A carriage supports the retrieval manipulator deployed vertically down. This enables the machine to be moved into position on rails over one of the three waste Vaults, or at a higher level the Chute Silo. The carriage has a 120 mm thick steel “Bell Housing”, which is suspended from the underside of the carriage, to maintain continuity of shielding over the Vault. It also provides an access point for tool changing and maintenance of the manipulator arm section. The entire manipulator mast and arm can rotate +/- 190 ° supported on a slewing ring mounted on the carriage. The manipulator maximum payload is 250kg at a reach of up to 5.6 metres.

The usual end effector is a special petal grab designed for picking up the waste, which fits within the deployment envelope, and handles the different types of waste present in the Vaults. Alternative tooling can be fitted for ad-hoc operations.

The waste retrieval manipulator is hydraulically powered and is remotely operated. The operator controls the machine via joysticks actuating proportional directional electro-hydraulic valves. An on-board camera is provided. CCTV cameras and lighting units are also provided to give a general view in the Vaults.

Recovery of Waste from Chute Silo

The Chute Silo wastes will be size-reduced into manageable elements, since it would be difficult to lift out and deal with very long, heavy objects (including the severed bomb-door pieces.) A variety of tooling and techniques, including hydraulic shears and thermal cutting, are currently being investigated. Self-contained tooling packages will be lowered into the silo, and the retrieval manipulator will pick up the size-reduced pieces and load them into a skip. A 4-rope winch system carried by a winch beam inserted into the Chute Silo is used to transport the skip into the silo. The skip is transferred out of the Chute Silo through a sidewall opening, which connects to the shielded transfer tunnel, where the waste joins the normal export route. In constructing the waste route it is necessary to remotely cut down the existing bomb-door mechanism originally used for loading the silo. A remote oxy-propane cutting tool has been developed for this purpose.

Two new holes cut through the roof provide manipulator access.

Fire Detection/Suppression System

The risk of fire in the Vaults is considered to be remote, but nevertheless a comprehensive fire detection and suppression system is provided for both the construction and operational phases of the project. (The Chute Silo is excluded as the stored materials are not combustible)

For fire detection, each vault is monitored separately with alarms relayed to 24 hour control centres. The sensors include hydrogen and optical smoke detectors.

The fire suppression system utilises argon from a bottled gas reservoir that can be discharged into any of Vaults 1,2,3 and 4. This is a simple manually initiated system, which would be used in conjunction with the Vault ventilation system to smother a fire.

WASTE PROCESSING

Process Cell Construction

The shielded waste-processing cell, 8m wide by 30m long by 6.5m high, is constructed within the existing Decontamination building, which provides a secondary containment for the cell. It has shield walls ranging from 0.6 m to 0.9 m thick. See Figure (4). The cell is finished with a decontaminable paint system, with stainless steel cladding in “wet” areas. A new 10te crane is installed which re-uses the existing rails provided for an obsolete building crane. Its principle duty is to transfer empty NIREX 3m³ boxes into the cell. It has been installed at the start of construction and used also for construction work.

The grout plant including two storage hoppers is installed adjacent to the Decontamination building with grout lines connected to the cell.

The facility contains interlocked shield doors for the receipt of waste into the processing cell, and for the dispatch of grouted NIREX waste containers to storage.

The process cell is ventilated by a system incorporating HEPA filters and has the primary filtration located inside cell. Two high capacity filter units are provided and can be remotely changed when necessary. The discharge is routed to the ventilation stack where all discharges to atmosphere are monitored.

A fire suppression system using argon can be operated under local management control, requiring manual initiation by key operated release valves following detection of an in cell fire. Fire extinguishing powder is also provided for local fire suppression.

In-cell operations utilise purpose designed mechanical handling and process equipment, and wherever practical in-cell machinery has external through wall drives, or else equipment can be recovered for repair in the event of breakdown. Lead glass windows provide the operator with a view, in conjunction with closed circuit television cameras. Master-slave manipulators (MSMs) are used for manual operations. A 5te capacity overhead x-y gantry hoist and a 1te travelling wall mounted boom hoist are provided in the waste receipt and storage area of the process cell. A 100kg jaw payload power manipulator which can hang from the crane-hook provides additional remote handling capacity. The grouting and export areas are provided with x-y hoists for handling drums and lids.

Operations in the waste-processing cell are carried out under manual control predominantly, in combination with a PLC control system, which controls sequential movements and certain more complex processes.

Preliminary Waste Processing Operations

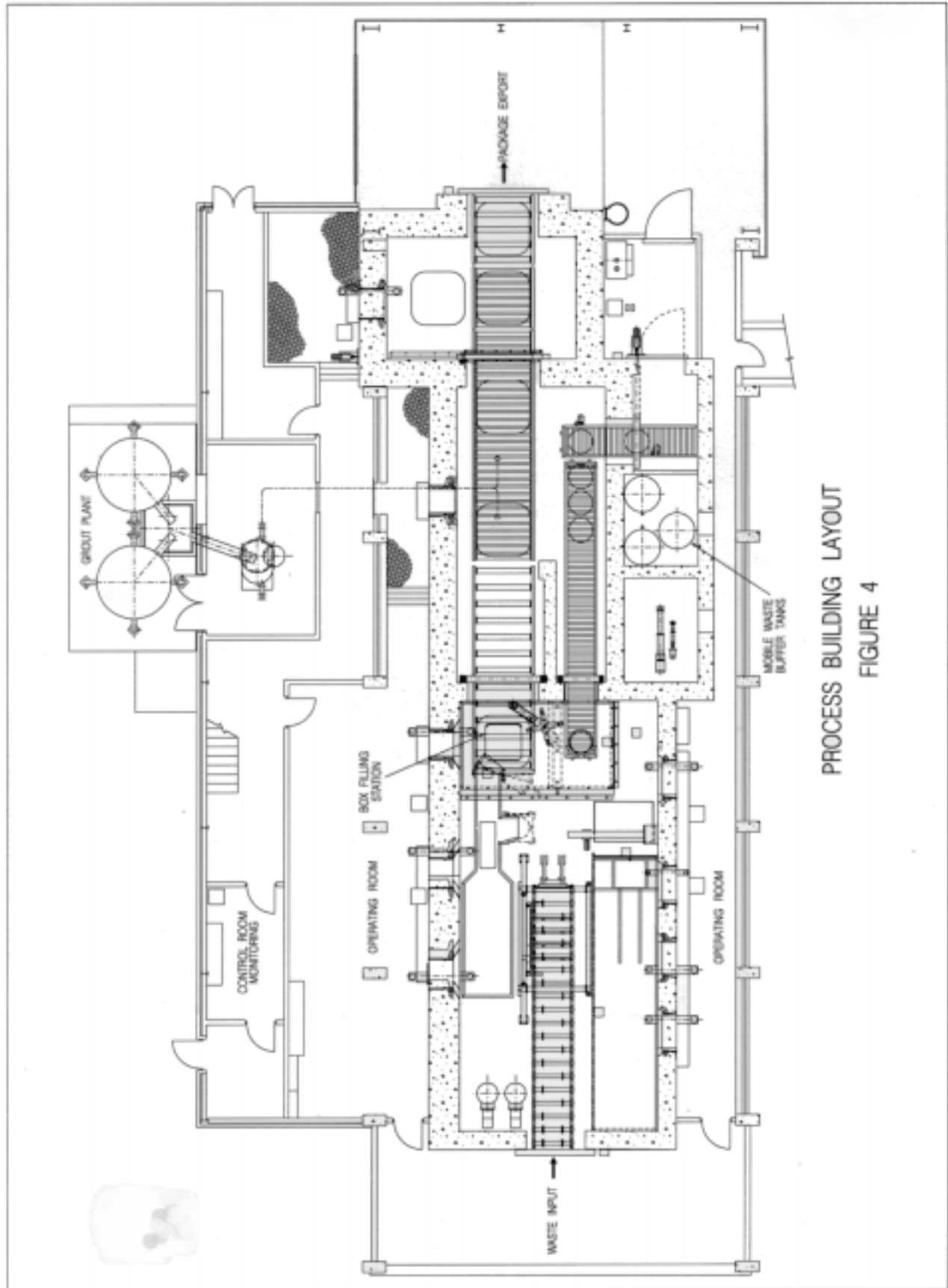
The overpack arriving at the process cell docks with the input shield door, forming a shielded enclosure. The overpack and process cell doors are opened together and the waste skip transferred into the process cell by synchronised powered roller conveyors. The skip lid is removed and canned wastes are removed from the skip by a powerful electromagnetic grab deployed by the in cell hoist. The cans are weighed, monitored and sentenced to either the mobile waste line or the solids line. Cans are opened using powered hand tools remotely operated using MSMs, in conjunction with a powered hacksaw. The empty containers are washed in an ultrasonic bath, and sentenced for disposal as LLW. Loose FED wastes are emptied by carefully tipping the skip contents onto a vibro table. The solid wastes and loose FED arriving at the vibro table are spread out, visually inspected and assayed using a gamma camera and a spectrometer. Any unacceptable material (e.g. fuel) can be removed by master slave manipulator and put into a shielded pot. The solid materials feed into either a 3m³ NIREX box, or 500 litre drum, at the appropriate filling station. A hydraulic tamping machine assists in efficient packing of FED. Data from in-cell radiometric instrumentation gives a fingerprint spectrum that is related to sampled analysed waste for NIREX waste package quality assurance records.

Solid Waste Grouting

A grout comprising Ordinary Portland Cement and blast furnace slag is required for encapsulating the solid waste in order to satisfy the NIREX wasteform requirements.

The contaminated waste receipt and sorting operations are isolated from the clean packaging operations by providing separate compartments in the process cell. A sealed door between the dirty area and the clean area is provided, as part of the waste filling station.

NIREX 3m³ or 500litre drum packages are introduced into the grouting area and transported on powered roller conveyors to the appropriate filling station. An inflatable seal incorporated in the seal door mates around the filling aperture of the box/drum to prevent contamination getting onto the outside surfaces of the box or drum. When this seal is inflated the sealed door opens and the box/drum can be filled with waste. An anti-floatation mesh is fitted into the box remotely when the box full. This is to prevent waste reaching the surface



during grouting. The door is then closed, the seal deflated and the box moved to the grouting position.

Grout from the grout mixing plant is pumped to the box grouting station. The box/drum is filled to the correct level as determined by local sensors. A grout cure period of 24 hours is required following which a 50mm cap grout (approximately) is added. After further curing the lid is fitted to the package. Following a contamination check it is weighed and exported to the ILW store in a shielded overpack by road transport.

Mobile Waste Line

The contents of the opened mobile waste containers are emptied into a water tank where they are sparged with clean water. A coarse filter mesh prevents unwanted debris passing into the mobile waste line. The pH is adjusted to 9.5 to 10 for corrosion protection, but higher pH is avoided to reduce the risk of hydrolysis of organic resins. The waste is re-suspended in the tank with the concentration adjusted to up to 14 Wt%. Radiometric measurements are taken, and the suspension is then pumped into one of two air agitated 1.8 m³ buffer tanks. Waste is held in the buffer tank until a sufficient batch has accumulated for transfer to the mobile waste store. This takes place via an existing 40mm shielded line using a progressive cavity sludge pump. The line is flushed with water after each transfer to clean the line hence preventing any tendency for sludge build-up and consequent blockage of the line. The water used for the mobile waste treatment and re-suspension is re-cycled and cleaned to minimise effluent.

WASTE STORAGE

NIREX Box and Drum Store

Circulator Hall 2A on the western side of Reactor 2 has been chosen for the location of the store for the processed solid and mobile wastes. This location was selected on the basis of safety, environmental impact and capacity. The circulator hall building has been demolished and a new reinforced concrete structure erected on the foundations to form the ILW box and drum store. It is unusual in being circular arced as a result. The capacity of the store is sufficient to accommodate all solid wastes in encapsulated form (up to 760 NIREX boxes or 500 litre drum stillages), stacked normally 5 high.

Encapsulated solid waste packages are received from the processing facility in a shielded overpack. The boxes are removed from the overpack through a transfer facility into the storage hall receipt point from where it is moved to its storage location by a remotely operated crane and grab provided for package handling. The boxes and drums are to be stored in such a manner that they can be inspected during storage. Features to permit the retrieval of the boxes into NIREX reusable shielded transport containers have been incorporated into the design.

Mobile Waste Storage in the CRP

The mobile waste storage facility re-uses two existing buildings, the CRP, which is situated approximately 200m from the process facility, and the AETP effluent treatment plant adjacent to the Vaults. The CRP houses redundant pond water effluent clean up systems and already contains a small quantity of mobile ILW in dedicated stainless steel tanks. The AETP is used for final effluent treatment, sentencing for authorised discharge.

Waste is transferred from the process cell to the storage vessels using a modified existing pipeline. Existing stainless steel vessels in the CRP are used, suitably modified, to provide

sufficient storage for mobile ILW and LLW wastes. ILW and LLW mobile wastes are deposited in the storage tanks by settling, and the supernate transfer liquors are decanted, and pumped off to the effluent treatment system. This can take place once the vessel contents build up to the decant leg level. The existing CRP filtration and ion exchange facilities are used to pre-treat aqueous effluent before discharge to the AETP for neutralisation.

Storage capacity for up to 148 M³ ILW mobile waste and up to 100 M³ LLW is provided.

SAFETY

Safety is the number one priority of all concerned on the Project. A joint approach between BNFL Magnox Generation and all contractors on the site ensures that co-ordination is maintained and standards remain high. Innovative approaches have been used to ensure that personnel at the workplace are directly involved in safety on site, and mechanisms necessarily put into place to enable feedback from the workers.

BNFL Magnox Generation review and approve all installation method statements and quality documentation to comply with their Site License requirements and the competence of all subcontractors and their personnel is reviewed.

PROGRESS TO DATE

Considerable progress has been made to date (January 99). All Phase 1 activities have been completed. The safety case submissions have been accepted and permission given to construct facilities with some caveats imposed by the regulatory authorities related to active break in to the Vaults. All major items of plant and equipment are under manufacture. Construction work on site is well advanced with the Process Cell built and installation of plant and equipment has commenced. The first major penetrations have commenced in the Vaults and the ILW Store and Mobile Waste Store are nearing completion. Non Active Commissioning is due to start during the middle of 1999.

The project team has tackled the challenges so far in an innovative and cost effective manner. Close co-operation has been necessary between the various design teams with differing backgrounds located in different countries. This has generally produced a good cross-fertilisation of ideas often with lively debate on how to achieve economic designs without compromising safety. It has been essential to work closely with BNFL Magnox Generation throughout the project to progress the work to our mutual satisfaction. The nature of the contract ensures that both parties focus clearly on making progress and avoid unnecessary expenditures.

The authors are grateful for the teams efforts and ingenuity and are confident that they will meet the challenges the future may hold.