RETRIEVAL OF PLUTONIUM-CONTAMINATED WASTE MATERIALS FROM INTERIM STORAGE

L .F. Johnson
Head of BNFL Waste Management Unit
British Nuclear Fuels plc
Sellafield, Seascale
Cumbria CA20 1PG
UK

ABSTRACT

Plutonium-contaminated solid waste materials (PCM) [contact-handled transuranic waste] originating from the early UK defence program were placed for interim storage in existing structures at Drigg, a site some 6km (4 miles) from Sellafield (formerly known as Windscale), the UK reprocessing and plutonium production site. The waste was contained within steel drums of up to 205 liters (55 US gallons) capacity or was contained in larger timber and plastic cuboid containment, known as "crates". The paper will describe the typical constituents of the drummed waste and of the crated waste, a proportion of which consists of redundant glove box facilities from the early production lines themselves.

British Nuclear Fuels plc (BNFL) became responsible for the Drigg site and waste stored on it at Company formation in 1971. In the mid-1970s, a commitment was given that PCM would be removed from the Drigg site leaving it to fulfil its role as the principal site in the UK for the disposal of solid low level radioactive waste from Sellafield and from elsewhere. Following a program of design and procurement of necessary facilities, retrieval of drummed PCM began in 1976. A team of operators, not full-time on this task, removed all drummed PCM from the existing storage structures, known as magazines, by 1986. This work is briefly reviewed in the paper.

Five of the magazines contain about 200 non-drummed packages which remain to be removed. Facilities to permit the retrieval of that waste have been designed and are now being procured and installed so that first retrieval can begin during this year.

The project team has addressed all aspects of safety and has needed to obtain necessary consents and authorizations from Her Majesty's Inspectorate of Pollution, so far as the safety of the environment and of members of the public is concerned, from Her Majesty's Nuclear Installations Inspectorate, so far as the safety of the workforce is concerned, and from the Department of Transport, so far as off-site transport which will follow retrieval is concerned. The paper describes key aspects of the safety case and the way in which project design and implementation will ensure adequate standards of safety throughout all aspects of the project.

INTRODUCTION

British Nuclear Fuels plc (BNFL) owns and operates the principal Solid Low Level Radioactive Waste (LLW) Disposal Site in the UK. The site is located at Drigg in West Cumbria some 6km (4 miles) to the south east of BNFL's Sellafield Site, the UK reprocessing and plutonium production facility.

PCM waste originating from the early UK defence program was placed for interim storage in existing structures, known as magazines, at Drigg. The waste was contained within steel drums of up to 205 liter (55 US gallons) capacity or in larger timber and plastic cuboid containers known as "crates".

In the mid 1970's a commitment was given that PCM waste would be removed *from* the Drigg Site thus generating additional space for the construction of new facilities for the disposal of LLW and leaving it to fulfil its role within the UK for the disposal of LLW.

In 1976, eight magazines on the Drigg site contained about 10 500 drums and some 200 non-drummed packages. Since then, most of the drums have been recovered and preparations are well advanced to retrieve the remaining material.

PLUTONIUM CONTAMINATED MATERIALS

PCM is a generic term used to describe a variety of solid waste materials which have become contaminated principally with plutonium compounds by virtue of their use inside the primary containment of plants engaged in fuel cycle or defence work. PCM is generally of low beta/gamma content.

Solid PCM arises in the form of:

- Small items sealed in PVC bags and contained in drums;
- Larger crated items (eg redundant glove boxes); and
- High efficiency particulate air (HEPA) filters from building and vessel vent/cabinet extract systems.

Combustible PCM is generally soft, low density, shreddable material such as PVC, other plastics, rubber, paper and clothing fabrics whereas non-combustible PCM comprises hard, high density materials such as glass, ceramics and metals.

The PCM remaining in Drigg magazines is generally contained in crates. Some of the items are known to be redundant glove boxes wrapped in PVC or other large plant items resulting from decommissioning or refurbishment. Contamination is generally by isotopes of plutonium, sometimes associated with isotopes of uranium, although it is also known that some of the waste contains tritium. Crate sizes can vary with sides of up to 5m length. The maximum weight expected to be encountered is about 4 tons. Many of the crates do not approach the maximum sizes.

GENERAL DESCRIPTION OF MAGAZINES

The magazines were provided as part of the Royal Ordnance Factory which formerly occupied the site. Each was a buffer store within which the high explosive product could be transferred to railway wagons for transport off-site.

A schematic view of a typical magazine is shown at Fig. 1. The magazines are similar in construction each comprising a reinforced concrete structure mounded over with earth.

The main features of the magazines are as follows:

- Receipt Bay - 30.5m long with former railway platform located down one side;
- Three large storage areas - having identical internal dimensions, of 4.5m wide by 8.1m long;
- Small storage area;
- Entrance room;
- Service corridor, surrounding the three large storage areas.

The whole magazine structure is buried beneath a 1.5m layer of soil, giving external dimensions of approximately 55m long by 40m wide. The magazines are constructed above ground and rise to an overall height of 6m above the surrounding ground level.

DRUM RETRIEVAL

Retrieval of the stored waste became necessary in view of the deterioration in the standard of containment, itself accelerated by ingress of rainwater through open end-faces of the magazines shortly after waste emplacement. For the drums, a procedure was developed to admit operators to each magazine in turn, maintaining magazine containment, so that each drum could then be checked, have containment improved by bagging or over-drumming as necessary, be checked free of contamination, be relabelled, have surface doserate recorded and be assayed for fissile material content.

Figure 2 shows the layout of a set of portable cabins which were sealed against the end-face of a magazine. Two sets of such equipment were used to enable retrieval work to proceed at all times.

Forced, filtered extract from the magazine was provided inducing an air flow across the changeroom barrier in accordance with usual arrangements. Provision was available permitting operators to enter the magazines in pressurized suits supplied by air line. This provision was utilized to varying degrees in most of the magazines, sometimes necessary only because portable equipment measuring any alpha activity in air failed to discriminate adequately at times between plutonium and high levels of radon/thoron.

In recognition that all of the drums would eventually require transport from the site, they were all provided with additional containment. Less than 1% of drums merited this from the results of inspection.

Fissile material assay was accomplished using a combination of direct weighing (from which density of the waste matrix was derived), low resolution gamma spectrometry (gives plutonium content result independent of burnup in reactor or age since separation, when energy band is carefully chosen for the measurement, and with an absorption correction based on matrix density) and passive neutron counting (for high density waste matrix). No reliance was placed on earlier records or labels. Some 10 500 drums were retrieved from the magazines and those magazines that were then empty were decontaminated as necessary and returned to unrestricted use.

The capital cost of the equipment employed was of order US $200 000 (mid-1970s money values), excluding the cost of an interim store which was constructed on the site as a buffer between the retrieval operation and subsequent off-site transport. Direct labor and supervisory input to the project averaged 3 man-years per year, with additional maintenance, management and operational Health Physics manpower input as required. Retrieval facilities were moved from one magazine to another by contractors, each move taking less than a week to a prepared hardstanding. Group average radiation dose uptake did not exceed 2mSv per annum during the drum retrieval project.

CRATE RETRIEVAL TASK

Five of the ten magazine stores on the Drigg Site contain a total of some 200 non-drummed packages still to be removed, and 110 drums which are presently inaccessible or too heavy for removal by manual means.

The items are to be retrieved, overcrated or redrummed, monitored and transported (within appropriate containment) by rail (in the majority of cases) and road links to Sellafield for subsequent storage.

DESIGN PHILOSOPHY OF CRATE RETRIEVAL FACILITIES

Overcrates and Drums

The project philosophy is that following retrieval, and for the duration of subsequent storage at Sellafield, the wastes will be provided with a high integrity containment.

For crates and large packages, the containment will be provided by an overcrate fabricated from glass reinforced plastic (GRP) with a core of fire retardant foam. Existing drummed wastes will be repacked into new drums and drumming of some of the other retrieved wastes will also be appropriate.

Design features of the overcrates include requirements:

- to receive loads up to a maximum of 7t for subsequent on-site and off-site transportation;
- to have a maximum leak rate of 12 1/h per m^2 of vertical surface for a 250 Pa (1" wg) suction (for the finally sealed crate);
- to have a leak rate of not more than 120 1/h per m^2 of vertical surface for a 250 Pa suction (inner closure panel and end panel temporarily fixed);
- no increase in leak rate following a minimum drop from at least 0.6m with full load;
- during a 10 minute petrol fire, the protection offered by the container should limit the temperature at the interior of the overcrate to a maximum of 80°C with no loss of containment;
- to be fitted with a HEPA filter to permit "breathing" after sealing;
- to have only one crate/package loaded into each overcrate.

Retrieval Via Magazine Modules

The design has been executed on the basis that in-magazine retrieval operations will be carried out in protective clothing (supplied air suits) with provision incorporated to achieve high integrity containment at points of export from the magazine, such that all subsequent operations will not require extensive use of protective clothing.

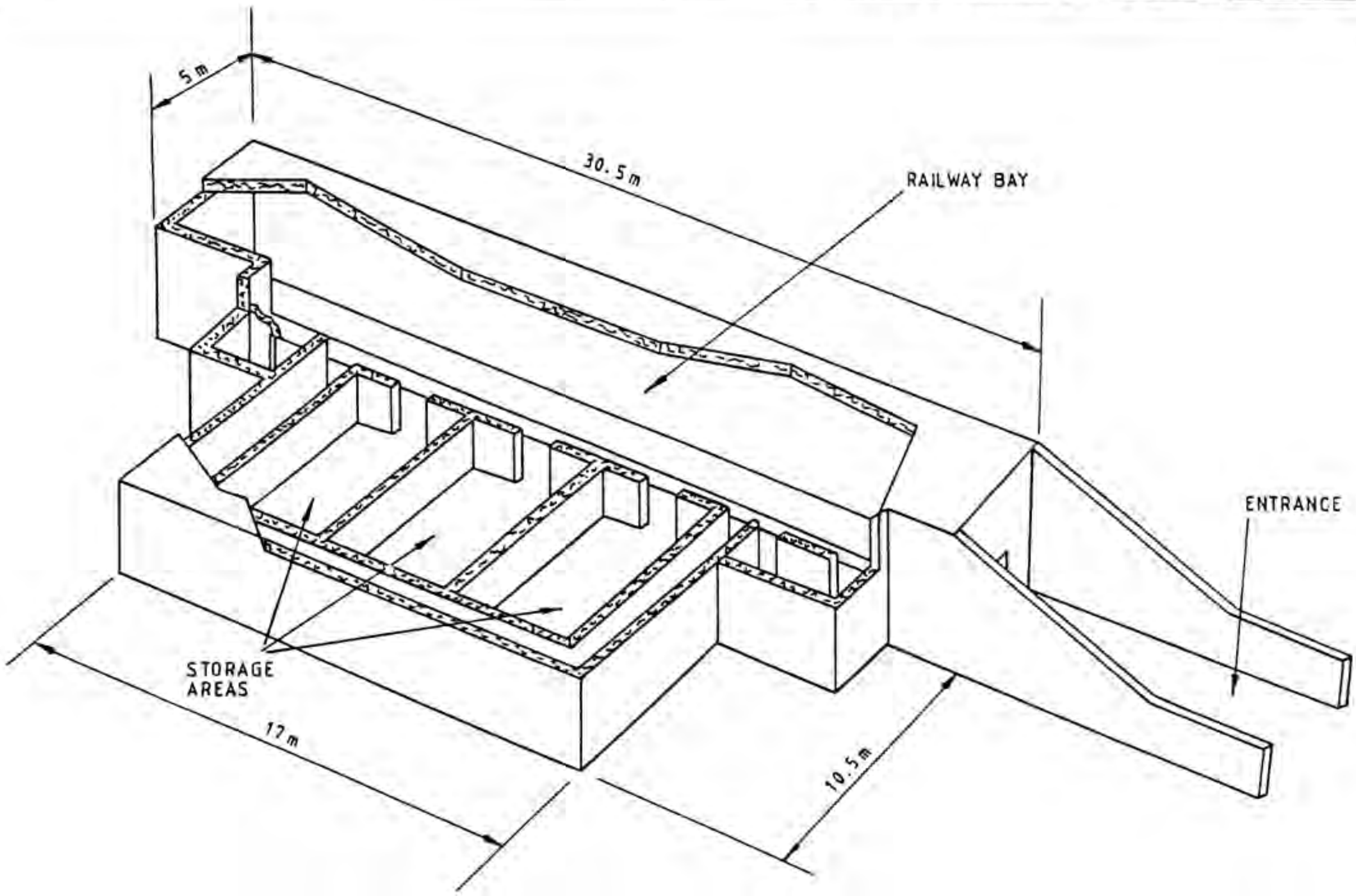

Fig. 1. Sectional view of Drigg Magazine.

The general philosophy is to provide a semi-permanent structure (Magazine Modules) for the controlled removal of PCM (see Figs. 3 and 4).

The existing magazines are to be extended by means of a purpose designed fabricated facility. The facility will be relocated at intervals of approximately one year in order to carry out operations at the five magazines containing PCM waste.

The modules are steel fabrications bolted together, incorporating weathertight sealed joints capable of multiple dismantling and re-erection over a five-year period without loss of alignment. Each module is thermally insulated with floors suitably reinforced to sustain a ten ton floor loading.

The modules when assembled, provide the following:

- access provision for personnel in protective clothing and the egress/undressing from such operations;
- a system for loading an empty GRP overcrate;
- a system for transferring the waste away from the magazine;
- capability for handling drummed retrieved wastes and wastes arising from the retrieval operations;
- possibility of decontamination and re-use;
- housing for equipment to assay the retrieved wastes for fissile content and uniquely to identify the overcrate and record the inventory.

The purpose of the magazine extension, two of the modules, is to:

- provide a clear and unobstructed operating area from commencement of in-magazine operations;
- permit orientation of retrieved crates/packages to align with the overcrate axis;
- permit the installation of equipment associated with the in-magazine operations, including early assay for fissile material inventory.

From knowledge of the relatively low prevailing dose rates within the magazines and that wastes being retrieved are PCM, the principal radiological hazard is considered to be the spread of contamination and release of airborne activity.

A dedicated ventilation extract system is provided to draw clean air through the modules (low contamination) to areas of higher contamination.

Fissile Inventory Monitoring

Considerable attention has been paid to appropriate fissile content assay systems. Initial monitoring takes place immediately out of the magazine environment in the magazine extension. Crates and drums are subsequently moved to a Central Monitoring Facility. Appendix 1 contains a fuller description of the assay systems.

Services and Interfaces

Arising from the identified operational requirements and design provisions, the following services are provided:

- dedicated ventilation extract system to draw air through the modules (low contamination) to areas of higher contamination;
- alpha-in-air monitors with audible and visual alarms installed in operating areas outside the magazines;
- control room to monitor in-magazine operations, instrumentation and alarms and surveillance of in-magazine operations;

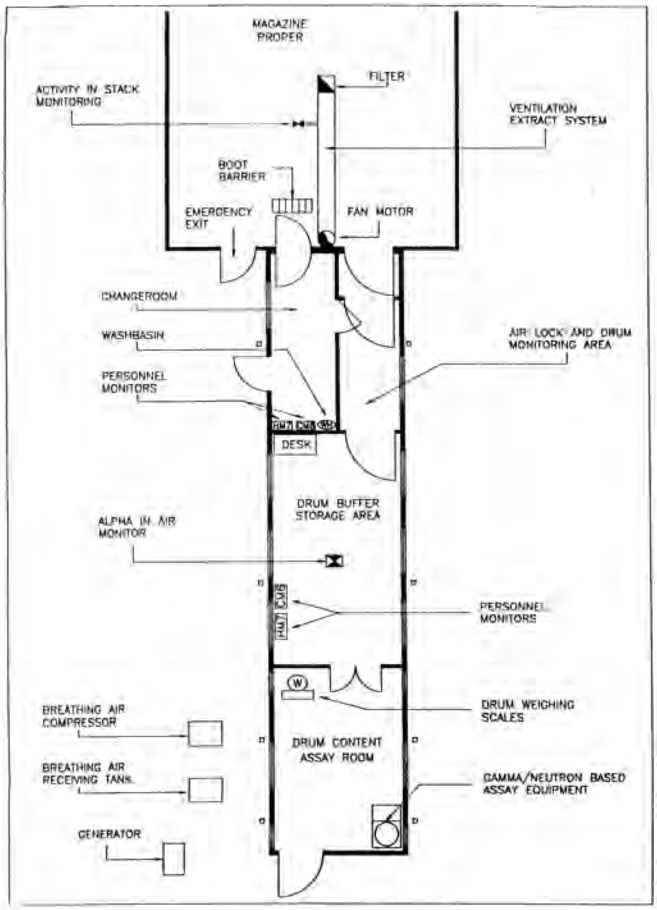

Fig. 2. Layout of portable cabins which were sealed against the end-face of a magazine.

- shower facilities for decontamination of supplied air suits on exit from the magazine;
- changerooms for entrance and egress of personnel;
- water supply and effluent handling system for changeroom and shower arisings;
- air compressor/receiver for supplied air suit air supply;
- electrical supply and switchgear/instrumentation to power services, lighting and instruments;
- gamma monitors in the magazine/extension.

PLANT DESCRIPTION

The Magazine Facility consists of eight basic areas: (See Fig. 3)

- Magazine Extension (modules 6 and 7)
- Crate Closure and Monitoring Area (modules 4 and 5)
- Crate Transfer Area (modules 2 and 3)
- External Loading Area (module 1)
- Control Room (module 8)
- Changeroom (including the Health Physics and Safety Department office with alarm repeaters) (module 9 and 10)
- Plant Modules (11-13)
- Monitoring Instrument Module.

Greater description of the plant provided for crate retrieval is given in Appendix 2. The capital cost of the equipment, including all the necessary overcrates and movement containers for the duration of the whole retrieval campaign, is of order US $11M (current money values). Direct labor and supervisory effort is expected to amount to 6 man-years per annum over a campaign expected to last for about five years. Maintenance, management and operational Health Physics manpower will be additional.

CENTRAL MONITORING FACILITY

The central monitoring building contains the following items:

Crate Monitor

The crate monitor located within the monitoring building is of sufficient size to enclose the largest overcrated PCM waste package and monitors each crate for up to 48 hours to obtain an accurate fissile material content.

Drum Monitor

The drum monitor located in the monitoring building is capable of accepting up to 500 l drums and uses total and coincidence neutron counting and gamma spectrometer techniques to determine the fissile content of all drummed waste.

Monitoring Control Room

An area of the monitoring building is partitioned so as to form the monitoring control room.

Storage Compound

Adjacent to the central monitoring building is a storage compound for monitored, unmonitored and unused overcrates and drums. Within this area the monitored overcrates and drums are loaded and secured inside ISO freight containers for transportation to Sellafield Site. Unloaded ISO freight containers are to be returned to Drigg for re-use.

ISO FREIGHT CONTAINERS

ISO freight containers provide the primary containment for both overcrates and drums when travelling through the public domain. The ISO containers are purpose designed in order to comply with safety requirements as stated in the 'Special Transport Authorization' submission for approval by the Department of Transport.

ISO freight containers 6.1m long x 2.4m wide x 2.6m high are used in conjunction with rail transportation and 6.1m x 2.8m x 3.6m high for road transportation. (Road transportation is used to convey a limited number of larger crates).

The containers are constructed from high yield steel (BS Specification 4360-508) and have demonstrated their ability to meet the tests specified for freight containers under para S23 of the IAEA Safety Series 6 1985 Regulations.

The containers are also tested and certified to be leak tight prior to each movement of PCM between Drigg and Sellafield.

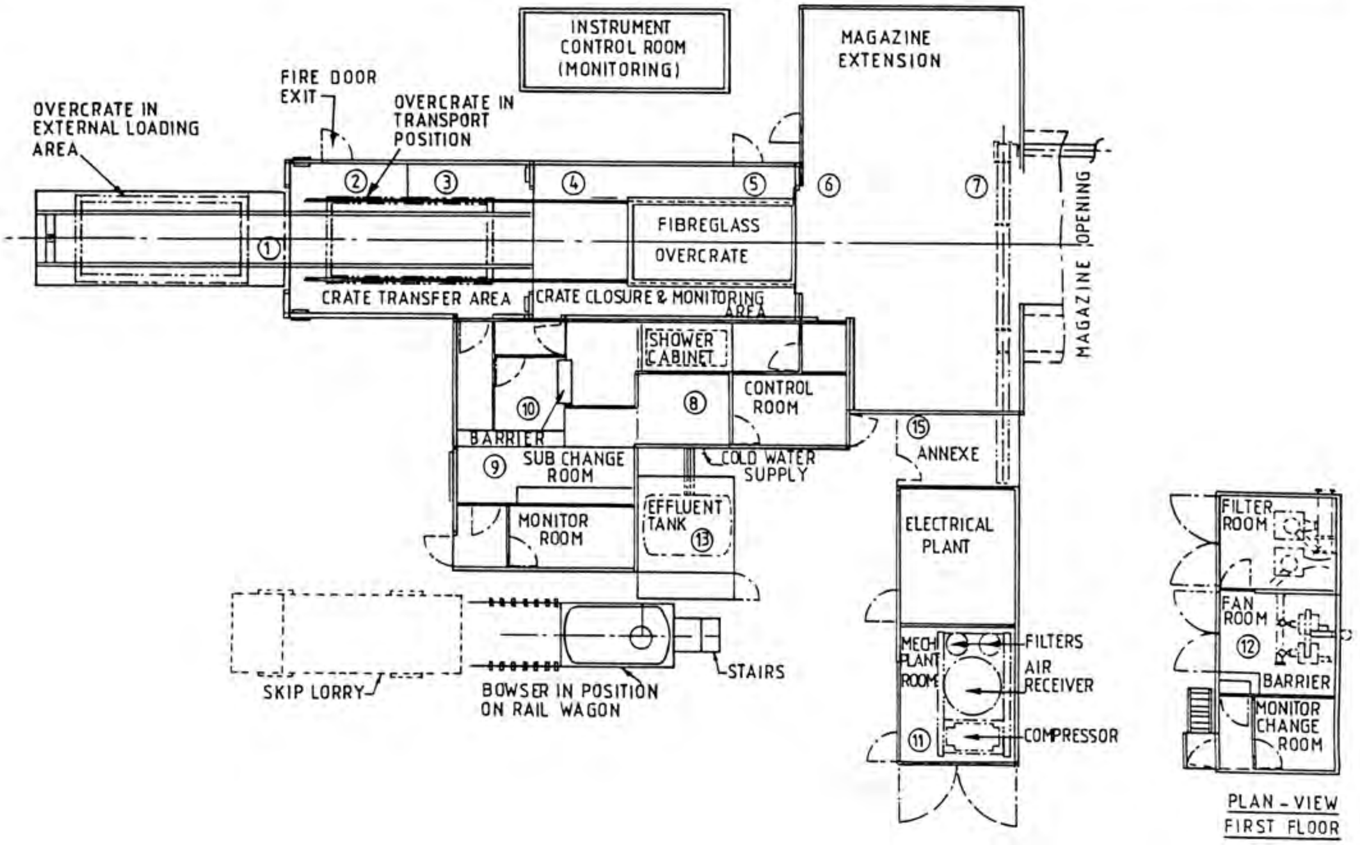

Fig. 3. Magazine module facilities.

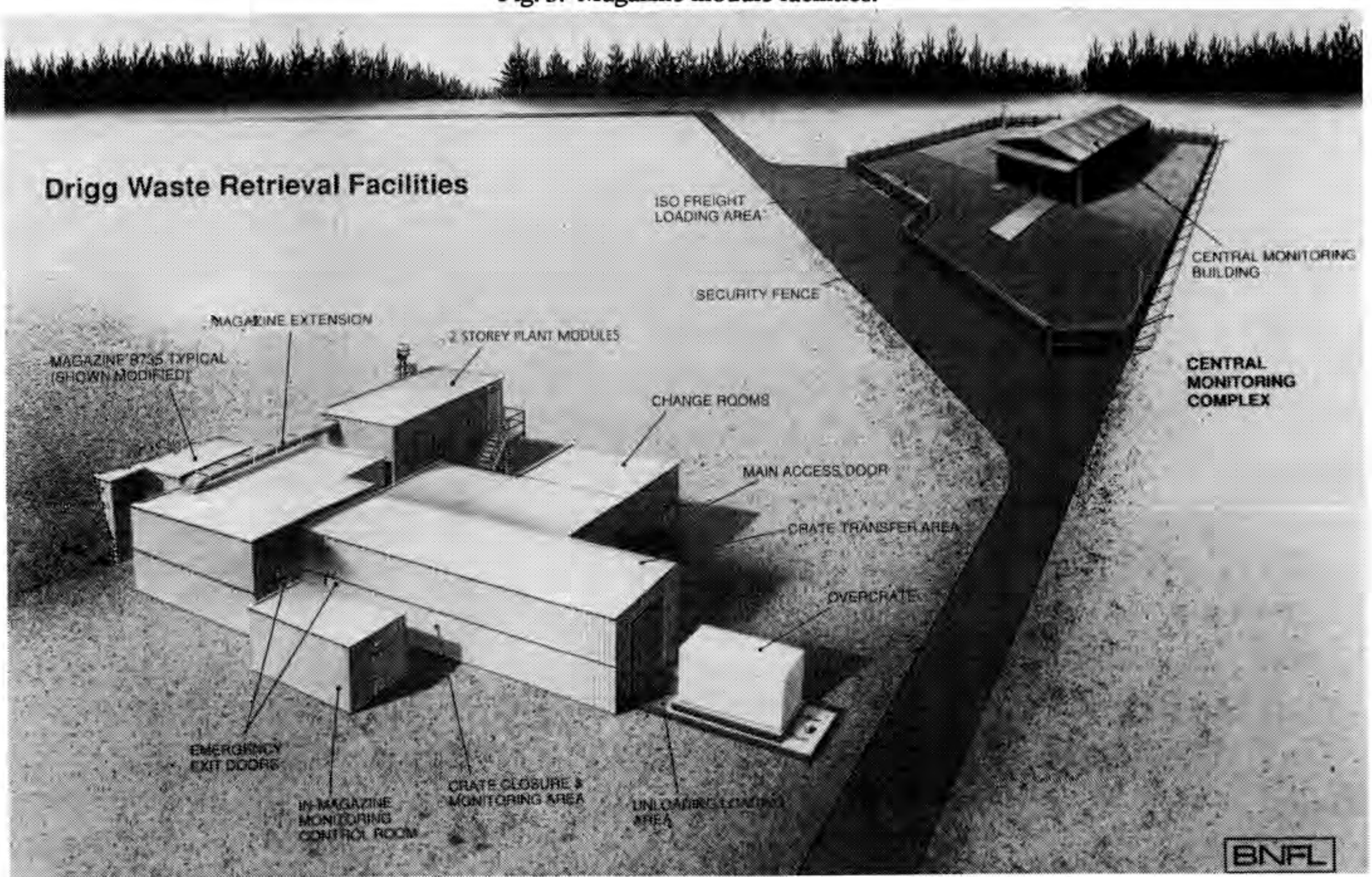

Fig. 4. Drigg waste retrieval facilities.

SAFETY

It will be appreciated from the foregoing descriptions that the retrieval facilities have taken account of the following key safety aspects:

- **Criticality**: measurement of the contents of crates/drums as close to point and time of retrieval as possible, following careful initial move;
- **Plutonium ingestion**: containment of magazines, contaminated areas and of the waste itself using physical barriers, air flows, developed transport containers, and suitable protective clothing for operators;
- **Fire:** minimization of combustible material loadings, including over-containment, with fire detection and alarm systems;
- **External radiation**: monitoring of items, use of suitable handling equipment, with area gamma radiation measurement and alarm systems;
- **Industrial safety**: suitable equipment will be provided for in-magazine and subsequent handling of heavy items.

During the crate retrieval campaign, group average radiation dose uptake is not assessed to exceed 5 mSv per annum.

PLANT WASTES

Solid Waste

Protective clothing will form a major constituent, the amount of more expensive clothing being minimized by the use of over-suits.

Liquid Effluents

In general, no liquids will be required in the magazine (as a result of design requirements). The exception will be hydraulic fluid (aqueous ethylene glycol) to operate the hydraulic scissor lift. The system is installed such that the hydraulic hose has a secondary containment within the magazine to prevent releases of aerosols/sprays.

There remains a possibility that fluid can arise in the magazine as a result of a spillage/leakage of a liquid associated with the wastes or as a result of rain water seepage which occurred prior to the magazines being sealed. Such wastes will be absorbed on to a suitable material and disposed of as solid waste.

Shower and wash hand basin water from the changerooms is the only envisaged design arising of liquid effluent. The effluent is accumulated alternately in one of a pair of holding tanks. For each tank there are alarms, sample systems, vents to atmosphere and a common secondary containment of stainless steel.

Future arisings on a weekly basis will effectively fill one tank. The contents are to be sampled and sentenced. The effluent is transferred to a bowser for transport back to Sellafield for treatment/discharge, if necessary, or if low enough in radioactivity is discharged to the Drigg site effluent system.

Gaseous Effluents

One of the principal design safeguards against the spread of airborne activity and contamination outside the magazine is the ventilation system.

The system draws air through the modules to the magazine. The aerial effluent passes through primary and secondary filters prior to discharge from a local stack.

The discharge is sampled and the flow recorded such that the annual discharge can be calculated and recorded. An alpha-in-stack monitor is installed to indicate an acute release of activity.

CONCLUSION

The drum retrieval operations were undertaken in the period 1976-1986, although the team of operators was not deployed full time on this task.

Crate retrieval operations are expected to begin this year, and to take about five years based on an initial estimate of one year per magazine.

APPENDIX 1

ASSAY SYSTEMS

Central Monitoring Facility Systems

The Crate Monitor and Drum Monitor both utilize neutron coincidence counting (NCC) and high resolution gamma spectrometry (HRGS) to determine the total plutonium content of crates and drums respectively.

The NCC measurement determines the combined quantity of those isotopes of plutonium which undergo spontaneous fission (called ^{240}Pu equivalent mass) by measuring the rate at which coincident neutrons are emitted. (Spontaneous fission results in the emission of two or more neutrons at the same instant from the decaying nucleus. Thus coincidence counting is sensitive to the mass of spontaneously fissioning plutonium isotopes but not to variations in (alpha, n) and background neutron rates).

The NCC chambers are cadmium lined (for nuclear safety reasons) and the measurement efficiency is therefore sensitive to the energy of the neutrons the instrument is trying to detect. Large quantities of moderating materials (polythene, plastics, wood, water, etc) in crates or drums could seriously affect the accuracy of the measurement. To minimize this problem, internal flux probes (unmoderated neutron detectors) are mounted on the inner surfaces of each chamber to measure the effects on the neutron energy spectrum of the moderating matrix in the crate/drum. The NCC derived estimates can then be automatically corrected according to the internal flux probe signals.

A further feature of the crate monitor is that the neutron count rates from each of 26 counting modules can be recorded independently to allow the distribution of strong neutron emitters within the crate to be determined.

The HRGS measurement determines the isotopic composition of plutonium in the crate/drum by measuring the relative intensities of several of the many gamma emissions of plutonium and ^{241}Am (a daughter product of ^{241}Pu). The isotopic composition is used together with the ^{240}Pu equivalent mass from the NCC measurement to determine the total plutonium content.

The HRGS measurement is also able to determine the time since separation of plutonium in waste, as well as to indicate the presence of ^{235}U and many fission products.

Magazine Extension Monitoring Systems

Total neutron counting (TNC) and low resolution gamma spectrometry (LRGS) are used to determine the plutonium content of PCM drums, whereas TNC and HRGS are used to determine the plutonium content of crates within the magazine extension.

These systems are provided to give safety-related information on fissile material content as close to the point of retrieval as possible. The Central Monitoring Facility enables definitive determinations to be undertaken for purposes including safety and accountancy.

TNC measurements determine the gross neutron emission rate from the crate/drum being investigated. However the accuracy of a measurement based on this technique alone is limited since TNC is sensitive not only to plutonium mass, but also to variations in specific neutron emission (SNE) caused by variations in plutonium isotopic composition, chemical composition, and associations with various light elements.

The HRGS measurement performed by the crate monitoring system can estimate the SNE of the plutonium within view of the gamma spectrometer by determining the plutonium isotopic composition and calculating the SNE assuming a chemical composition (usually PuO_2). Thus, the accuracy of TNC measurements can be significantly improved by estimating the SNE via HRGS measurements.

The relatively simple LRGS measurement performed by the drum monitoring system can be used in one of two ways:

- To determine the plutonium mass directly. This option is chosen for drums with a low mean density (determined by weighing) where it is expected that there will be relatively little gamma ray attenuation. The plutonium gamma ray count rate in the gamma energy range 355 - 405 keV is determined and used to calculate the plutonium mass estimate directly. However, in the event that a low mean density drum is found (via the LRGS measurement) to contain significant levels of fission products, the LRGS measurement of plutonium mass will be discarded and the plutonium mass will be calculated from the TNC measurement instead. (Large quantities of fission products would produce intense, high energy (600 - 1500 keV) gamma emissions which would distort the plutonium measurement region causing a significant overestimate of plutonium mass).
- To select the TNC calibration for the plutonium SNE. This route is chosen for drums with a high mean density (determined by weighing) where the amount of matrix present would severely attenuate the gamma ray emission but would generally have little or no effect on the neutron emission. The plutonium isotopic grade is determined from the relative intensities of two regions of the gamma ray spectrum, and the appropriate TNC calibration is chosen.

APPENDIX 2

CRATE RETRIEVAL PLANT

Magazine Extension (Modules 6 and 7)

The magazine extension is mounted directly on to the face of the existing magazine and is continuously open to the magazine environment. The extension contains the drum/package monitor, initial crate monitor, PCM weighing equipment and is sized to allow 360° rotation of all crates for handling and monitoring purposes. The link to the crate closure and monitoring area (modules 4 and 5) is via a roller shutter door.

Crate Closure and Monitoring Area (Modules 4 and 5)

An empty overcrate is located within the module using a floor mounted roller/track system. After a crate has been loaded, the overcrate is monitored for contamination and external radiation doserate. Containment between the crate closure/monitoring area, the overcrate and the magazine extension is maintained by a combination of roller shutter door, flexible curtains and ventilation air flow.

Crate Transfer Area (Modules 2 and 3)

This module is interposed between the crate closure and monitoring area and external loading areas to create a contamination check barrier.

External Loading Area (Module 1)

A floor mounted roller and track system extends from the crate monitoring area through the transfer module on to the concrete apron which forms the external crate loading area. From this position loaded overcrates/drums are dispatched to the central monitoring complex and empty overcrates/drums enter through the facility to the magazine work area.

Magazine Facility Control Room (Module 8)

The control room contains TV monitors for surveillance of the in-magazine work areas, transfer and crate closure modules. An intercom system connects all work areas to the control room. In addition to breathing air supply controls there are ventilation stack flow indicators, effluent level indicators, fire and environmental alarms.

Changerooms (Modules 9 and 10)

These facilities are designed for highly contaminated supplied air suit operations. Consequently they contain shower units, hand washing facilities and personnel monitors.

Plant Modules (Modules 11-13)

The two-story plant modules are segregated from the magazine facility and contain:

- Breathing Air Compressor (Module 11)
- Electrical Switch Room (Module 11)
- Ventilation and filtration equipment, with discharge stack (Module 12)
- Suitable electrical supplies.

In-Magazine Extension Monitoring Control Room

The monitoring control room is situated adjacent to the magazine extension and contains the monitoring instrumentation control racks and data recording equipment for the in-magazine extension package/drum monitor and crate monitor. All in-magazine extension fissile material monitoring is controlled from this building.