FACILITIES FOR PROCESSING, PACKAGING AND STORAGE OF INTERMEDIATE LEVEL RADIOACTIVE WASTE AT THE WINFRITH TECHNOLOGY CENTER

A. I. Lloyd, M. S. T. Price and A. T. Staples
Winfrith Technology Center, UK

ABSTRACT

The UK strategy for the management of radioactive waste is the responsibility of the Secretary of State for the Environment. The implementation of that strategy is a function of Her Majesty's Inspectorate of Pollution (HMIP), a department within the Department of the Environment. Close liaison between HMIP and Her Majesty's Nuclear Installation Inspectorate (HMNII) takes place ensuring that site licenses are only granted for proposals which are consistent with the national waste management strategy.

The task of developing national low level solid waste (LLSW) and intermediate level waste (ILW) disposal facilities rests with the UK Nirex, Ltd., a company formed by major national nuclear utilities with independent and government representation. This company is currently investigating the suitability of Sellafield, Cumbria and Dounreay, Caithness for a national repository. Operation of such a facility is unlikely however before the year 2005.

UK INDUSTRY

Major producers of radioactive waste in the UK include the UK Atomic Energy Authority (UKAEA), British Nuclear Fuels plc (former the production arm of the UKAEA) and the Nuclear Electric Division of the Central Electricity Generating Board (CEGB). Each of these organizations has its own strategy for the management of radioactive wastes because of local and historical considerations. They must nevertheless be compatible with the national strategy.

UKAEA

The UKAEA has recently undergone a major corporate review and, as part of this, a new trading name of AEA Technology has emerged containing nine functionally-oriented businesses operating out of the seven sites in the UK. One of these is the Decommissioning and Radwaste Management Business (D&R) which is subdivided into task specific divisions, one of which is the Radwaste Operations Division. As part of the Radwaste Operations Division, two ILW treatment and storage facilities are being introduced; one at Dounreay, Caithness and the other at Winfrith, Dorset. The current strategy plans that these treatment facilities deal with the majority of alpha/beta/gamma operational wastes generated by AEA Technology and held in store. A further facility will be required for the treatment of alpha-bearing operational wastes.

AEA TECHNOLOGY, WINFRITH

One of AEA Technology's major operating facilities is the Winfrith Technology Center (WTC) situated in Dorset. The site has two major facilities producing intermediate level waste (ILW), namely the heavy water moderated, light water cooled Steam Generating Heavy Water Reactor (SGHWR) and a Post-Irradiation Fuel Examination (PIE) facility.

CURRENT SITE WASTES AT WINFRITH

Sludges

Over the approximate 20 y operational life of the SGHWR, periodic decontaminations of the reactor primary circuits and cooling water treatment have led to the accumulation of ~240 m^3 of 30 wt% aqueous sludge. While the reactor continues to operate, sludges are generated at the rate of about 10 m^3/y. This waste is currently stored in three tanks each 7.3 m square and 4.5 m deep. The settled sludges are covered by a layer of liquid which provides shielding. Current routine discharges to these tanks are allowed to settle and clear supernatant liquid is discharged to the site collection and sentencing tanks from which it is discharged, in compliance with strict authorization procedures, via a pipeline to the sea with other low level liquid waste (LLLW).

The main constituents of the sludge are:

- Ion exchange resins, principally Powdex resins, which form 85% by weight of the sludge.
- Stella filter aid (Material A) used for pond water cleaning. In addition to this, precoat Solka floc BW40 has been used, which is a cellulose filter aid. These materials when backwashed form a sludge with the ion exchange resin.
- Lime used to precipitate organic ions in the sludge.
- Various metal oxides.
- Sludges from chemical cleaning of the primary circuit.

Although grab samples indicate that all of the tanks contain essentially similar materials, they are extremely heterogeneously layered and two tanks have been characterized in detail by homogenization (1). The major radioactive components of the sludges are associated with activated corrosion products. A typical radiochemical analysis is given in Table I and the median particle size is about 40 μm.

The tanks are reaching the end of their operational lives and decommissioning of these tanks is the ultimate objective of the WTC strategy. However, a phased approach is being adopted which is consistent with both UK policy and operational requirements. It involves the homogenization and removal of the bulk of the sludge, followed by removal of solid "undeclared" objects and the remaining sludge from the base of the tanks and then complete removal of the tanks themselves.

Solids

Since the cessation of sea disposal in 1982, solid waste has been collected and stored on site in shielded drums. The wastes are contained in mild steel drums of three different sizes (27, 55 or 150 liters) within the core of the concrete shielded drums. Some 400 of these drums are currently in store.

Two principal sources of this waste are from SGHWR or the PIE caves. In the former case, waste is primarily activated material and in the latter it is contaminated with irradiated fuel debris. These wastes are trade wastes from maintenance work, housekeeping wastes and redundant pieces of equipment.

A database containing the origin of waste, the date of arising and surface dose rate on the exterior of the concrete drum is maintained. Typical radiochemical inventories for these drums are shown in Table II.

Some drums from the aborted sea disposal operations planned for 1983 and 1984 are also held on site. These are fully prepared drums and the forward strategy is to examine methods of preparing them for land burial.

Radioactive Waste Strategy at WTC

The ILW strategy is to treat current arisings in a safe manner consistent with UK policy while maintaining flexibility to treat other arisings in the future.

Three major facilities are in various stages of construction/ design at the WTC, viz:

1. The Sludge Homogenization Plant, code-named STRATOS,
2. The Radwaste Treatment Plant (RTP) within the Radwaste Treatment Building (RTB), and
3. The Treated Radwaste Store (TRS).

Each of these will be described showing how they achieve consistency with the overall strategy.

The STRATOS Sludge Homogenization Plant

This plant is to be built adjacent to the sludge tanks on

TABLE I
RADIONUCLIDE ANALYSIS OF WINFRITH REACTOR SLUDGE

Nuclide	1/2 Life	Detection Method	Measured Value for Supernatant Bq ml^{-1}	Measured Value on Ashed Sludge Bq g^{-1}	Calculated Value for Air Dried Sludge Bq g^{-1}
Co^{60}	5.27y	gamma	1×10^1	1×10^6	2×10^5
Mn^{54}	291d	gamma		1×10^4	2×10^3
Zn^{65}	245d	gamma	1×10^1		
Cs^{137}	30y	gamma	1.2×10^3	6×10^4	1.2×10^4
Total Beta		beta	1×10^3	3.5×10^5	7×10^4
Sr^{90}	28y	beta	2	3×10^3	6×10^2
Ni^{63}	92y	beta	5	1×10^5	2×10^4
Fe^{55}	2.7y	beta	≤ 1	6.5×10^5	1.3×10^5
U^{238}	4.5×10^9y	alpha		2.3	4×10^{-1}
U^{235}	7.1×10^8y	alpha		9.1	1.8
Pu^{239}/Pu^{240}	2.4×10^4y	alpha		3.8×10^1	7
Am^{241}	450y	alpha		6×10^2	1.2×10^2
Cm^{244}	17.6y	alpha		2×10^1	4
Cm^{242}	163d	alpha		2×10^1	4

TABLE II
AVERAGE NUCLIDE CONCENTRATION (TBq m^{-3}) IN SOURCE DRUMS

	Activated Corrosion Products		Mixed Fission Products	
	Drum Volume			
Nuclide	55 Liter	150 Liter	26 Liter	150 Liter
Co^{60}	4.3×10^{-2}	8.9×10^{-3}		
Cr^{51}	6.7×10^{-4}	1.4×10^{-4}		
Co^{58}	2.0×10^{-3}	4.2×10^{-4}		
Mn^{54}	3.4×10^{-3}	6.9×10^{-4}		
Zn^{65}	2.0×10^{-3}	4.2×10^{-4}		
Fe^{59}	1.3×10^{-3}	2.8×10^{-4}		
Zr^{95}	5.4×10^{-3}	1.1×10^{-3}	3.4×10^{-2}	1.8×10^{-3}
Nb^{95}	9.4×10^{-3}	1.9×10^{-3}	3.4×10^{-2}	1.8×10^{-3}
Cs^{137}			1.1×10^{-1}	5.8×10^{-3}
Cs^{134}			3.4×10^{-2}	1.8×10^{-3}
Ce^{144}			1.1×10^{-1}	5.8×10^{-3}
Pr^{144}			1.1×10^{-1}	5.8×10^{-3}
Sr^{90}			7.4×10^{-2}	3.8×10^{-3}
y^{90}			7.4×10^{-2}	3.8×10^{-3}
Ru^{106}/Rh^{106}			1.4×10^{-1}	7.3×10^{-3}
Pu^{239}/Pu^{240}			9.9×10^{-4}	5.1×10^{-5}
Pu^{238}			9.9×10^{-4}	5.1×10^{-5}
Cm^{243}/Cm^{244}			3.0×10^{-4}	1.6×10^{-5}
Cm^{242}			3.3×10^{-3}	1.7×10^{-4}
Am^{241}			5.3×10^{-4}	2.7×10^{-5}

the SGHWR site and consists of two parts:

a. Homogenization and conditioning equipment,

b. Support facilities, e. g., maintenance/decontamination facilities and various power and ventilation services.

The specialized equipment covers three main process events:

- Homogenization and pump out,
- Conditioning and
- Transfer to the cross-site transport container.

The homogenization equipment consists of four cubicles mounted above a sludge tank, each of which contains a shielded top, entry to the tank and a submersible electric mixer with near 360° operation which can be remotely lowered and operated. This equipment has been proven during experimental work and will homogenize the sludge to ~14 w/o consistency. Each tank will be sampled and analyzed prior to further treatment. Once homogenized, the sludge will be removed using a centrifugal pump along a coaxial pipe within a shielded duct to the conditioning tank within the main building.

The conditioning plant, consisting of a conditioning tank and supernatant liquid discharge tank are housed within a shielded cell which has no plant requiring routine maintenance. All transfers utilize vacuum techniques and all control and instrumentation use either re-entrant equipment or pneumercators. Adjacent to this cell is a lightly shielded cell containing an off-gas scrubber, density measuring equipment and other active maintainable equipment. Plant throughout is specified as 5 m^3 conditioned (~30 w/o) sludge per week which is equivalent to approximately 11 m^3 homogenized (~14 w/o) sludge. The conditioning plant is capable of achieving this target in one batch. Approximately 11 m^3 homogenized sludge is transferred to the tank and allowed to settle for 24 hours after which time excess liquid is vacuum transferred into the "supernate" vessel. The concentrated sludge is then checked for density and any corrections made by further addition of water or removal of supernatant. This is sampled and analyzed prior to being discharged as low level liquid waste. Facilities are available at this stage to dose the conditioned sludge to improve performance during cementation if required. From the conditioning vessel, conditioned sludge is discharged by vacuum to the metering tank.

A preset quantity of sludge is charged to a shielded metering vessel from which it can be moved either to the RTP for direct cementation or to the TRS for storage. The sludges contain high levels of organic materials which may need to be removed (3). The current flow sheet must therefore permit either direct cementation using the RTP or organic destruction prior to cementation in the RTP.

The Radwaste Treatment Plant and Building

The building housing the RTP is designed to be flexible so that it can supply services to any plant that may be built during its lifetime.

It is 17.7 m high, approximately 35 m long and approximately 32 m wide. It consists of a main hall formed by a clear span portal frame with a 15 m eaves height, flanked on each side by multi-story annexes which hold plant and personnel facilities.

The main hall also includes a 2 m deep pit around the perimeter of which various building supplied processes may be accessed and from the base of which various process plants can be built. At one corner of the pit is a sump 2.25 mm deeper than the main pit housing the active liquid effluent plant and equipment.

The superstructure generally is comprised of an aluminum-clad structural steel portal frame. The side annexes are integral with the main hall portal frame and comprised of a precast concrete floor unit with in situ structural screen topping, supported on a structural steel frame.

The building provides the following services:

- Active and inactive ventilation plant,
- A 50 te gantry crane spanning the cell hall,
- Active and non-active drainage,
- Compressed air,
- Water services (fire, drinking and treated),
- Electricity (mains, diesel back-up and guaranteed non-interruptible),
- Heating via gas-fired boilers,
- Workshops,
- Change rooms,
- Public address and alarm systems.

The Radwaste Treatment Plant (RTP) is located within the main hall of the RTB and is shown in Fig. 1. The central

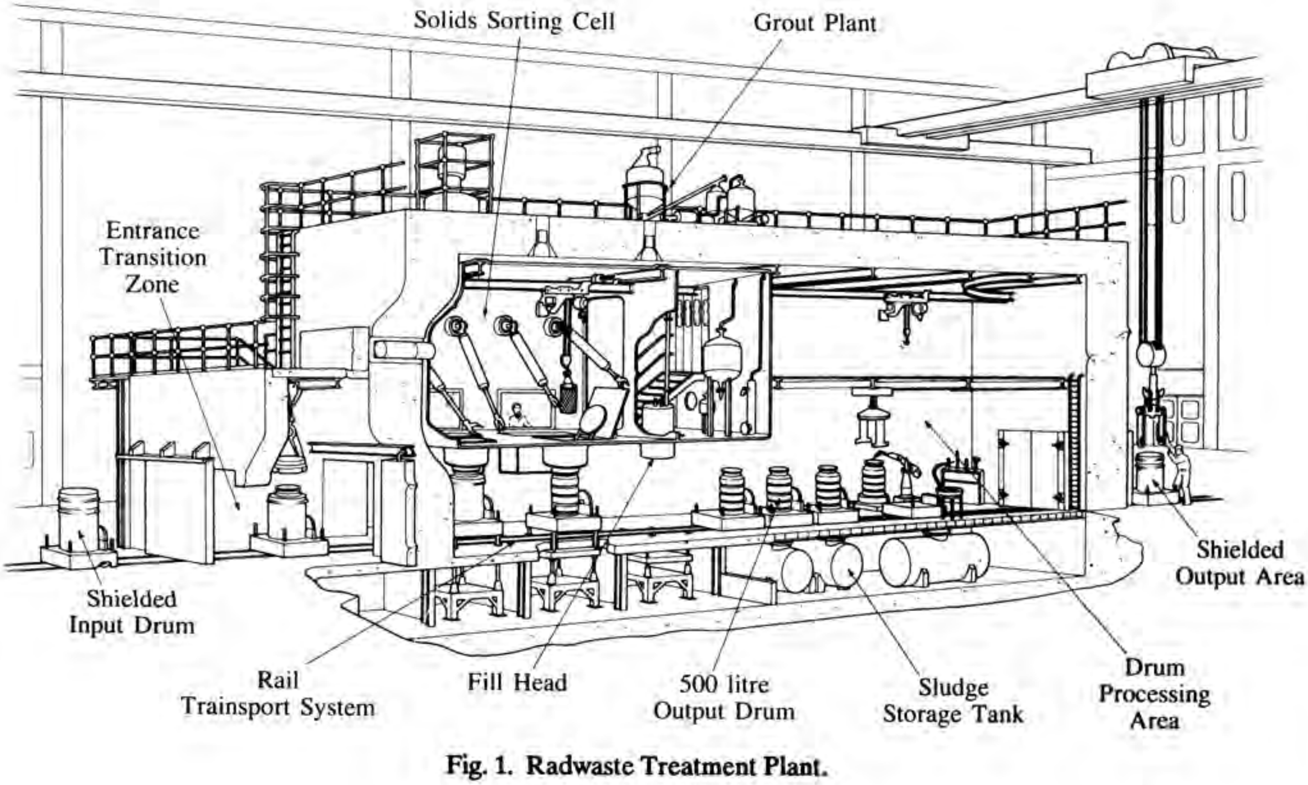

Fig. 1. Radwaste Treatment Plant.

feature of the RTP is a drum transfer tunnel, (20 m x 4.5 m x 3.6 m high) through which runs a double line, single-track rail system at the O meter level. The tunnel has shielded double-door gamma gates at the entrance and exit ends and is shielded along the sides and roof by precast concrete blocks grouted in situ (to ease decommissioning). Shielding is provided to attenuate a point source of 370 GBq Co^{60} gamma dose to an external surface dose rate of 2.5 $\mu Sv\ hr^{-1}$, a requirement which is considerably in excess of that needed for the on-site waste streams.

The basement area, the -2m level, contains mechanical jacking stations and three tanks; an effluent collection tank and two holding tanks. Attached, but exterior, to the basement bulk shielding is a lightly shielded primary ventilation filter room. This contains the high-efficiency particulate air (HEP) filters from the RTP segregated cascaded active ventilation system.

Above the tunnel, at the east end of the plant, is a mild steel primary containment box, the sort cell (6 m x 4 m x 4 m) within the bulk shielding. This is equipped with zinc bromide viewing windows and penetrations for four pair of manipulators, a programmable logic-controlled hoist and two posting ports communicating with the tunnel (hydraulically-operated) and designed to maintain primary containment when attached to a 500 liter disposal drum.

Adjacent to the sort cell is the metering cell containing a metering tank and fill head which provides a primary containment extension to the 500 liter disposal drum enabling either grout powder or liquor discharge to the drum. It also contains a hydraulic motor to drive the in-drum paddle. A liquor handling system is provided within the plant for the transfer of liquor to the metering tanks from the holding tanks in the basement. Provision is made for future installation of a primary containment decontamination cell although currently only a lifting beam is provided in this area.

A standard industrial grout production plant and powder-handling plant fed by bulk silos exterior to the RTB is provided above the roof shielding of the RTP.

The RTP will be operated on a campaign basis for either sludge or solid encapsulation. It is designed for a throughput of four drums of sludge or two drums of solid waste per normal working day. In the initial campaigns, it is probable that waste will be brought to the plant in 500 liter disposal drums, whose development was, described at Waste Management '89 (Ref. 4). The drum will be in a shielded overpack and the package will be loaded onto a programmable logic-controlled (plc) battery-powered trolley. After the trolley has reached the entrance zone, the secondary containment lid is removed. The trolley then passes via the gamma gate to the fill head position where either premixed grout or dry cement powders are added until the volume of waste and cement is just beneath the primary containment splash plate. Premixed grout which is made from a 3:1 mixture of Pulverized Fuel Ash and Ordinary Portland Cement and water is used to infill the spaces between solid wastes. The dry cement powders are added to the sludge and consist of a 9:1 mixture of Blast Furnace Slag and Ordinary Portland Cement. Details of the development of these formulations are given in Refs. 5 and 6. After curing for 24 hours, the drum and trolley pass to a quality control station. Here the drum is removed from the overpack which remains on the trolley and is placed upon a turntable adjacent to a robotic arm. The robotic arm performs a number of disparate functions, namely:

1. Tack welds the inner lid to the main drum (solids only),
2. Pierces pre-weakened zones in the inner lid,
3. Checks the penetration resistance of the matrix,
4. Removes any overstanding liquor from the matrix surface,
5. Places the drum lid on top of the drum, maps the lid drum interface and then welds the lid using synergic metal inert gas (MIG) techniques,
6. Fills the interspace between the inner and outer lids with grout,
7. Welds a final closure cap onto the outer lid,
8. Smears the external surfaces of the drum and monitors for contamination.

The drum is then replaced into the overpack, the overpack shield lid placed and the completed package passes via the exit gamma gate on the trolley into the RTB cell hall where it is loaded onto a wagon for transfer to the store.

All plant operations are controlled via a plc system housed in the plant control room which is in the cell hall adjacent to the RTP.

Treated Radwaste Store

The basic design philosophy has been to provide a long term store capable of holding all completed drums necessary to clear the current WTC backlog of waste with necessary receipt and periodic checking facilities as well as being capable of simple and cheap extension. Provision for the eventual removal of waste drums in a shielded overpack to the national repository has also been made.

The accommodation provided within the store, Fig. 2, may be subdivided into six areas.

- The vehicle drive-through facility,
- Receipt/Dispatch area,
- Control room and service area,
- Quality assessment area,
- Drum store and
- Extension area.

The vehicle drive-through facility is designed to be able to act as a common facility which could be constructed adjacent to the store. Here the wagon containing the over-packed drum from the RTP arrives. The receipt/dispatch area is bounded by a shield wall. Single drums, within their overpacks, are moved into this area from the transporter. The drum is then remotely removed from its overpack and can be transferred to a Quality Assessment unit or to a buffer store both of which are within this area. Visual inspection of the drum surface, surface contamination monitoring and bulk γ measurements form essential parts of the Quality Assessment unit. Facilities also exist for decontamination should this prove necessary. To prevent crevice corrosion cracking between the 500 liter stainless drums, a sacrificial carbon steel spacer will be placed on each drum prior to transfer to the main store. Drums will be examined in this unit on receipt, at intervals during storage and prior to dispatch. The control room and services area provide basic facilities for store operation. Camera systems are installed to aid remote operation and to read the drum identification markings. Crane maintenance and decontamination areas are provided on upper floors. The waste drums are to be stored within vertical arrays of interlocking capped tubes using standard, commercially available, concrete pipe rings. These are shielded on three sides and on the fourth side by a temporary shield wall formed by two rows of tubes filled with granular material. Each tube can hold up to ten drums and is fitted with a removable shielding cap which has a lifting feature identical to the drum. To increase the storage capacity following erection of further tubes, the granular material in the tubes forming the temporary shield wall can be transferred to other tubes by suction to provide a new shield wall.

As a further aid to flexibility, the store is capable of holding drums of uncemented SGHWR sludge as an interim measure until the need for organic destruction is clarified.

CONCLUSION

AEA Technology has facilities at the Winfrith Technology Center which:

- Provide a complete waste treatment and storage service for ILW generated on the Winfrith site.
- Have been designed with maximum flexibility so that they have the potential to be expanded to treat other types of ILW.

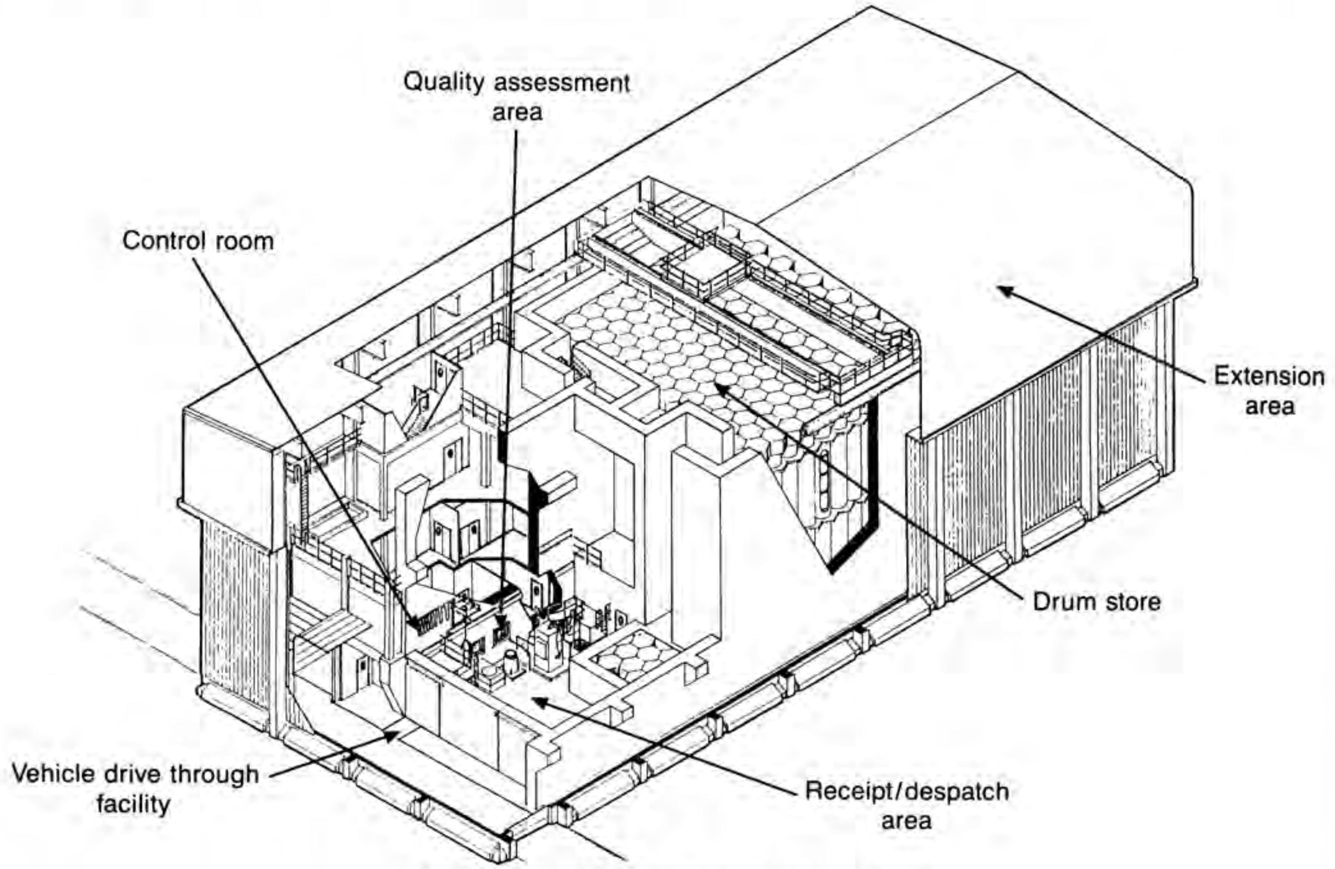

Fig. 2. Treated Radwaste Store AEE Winfrith.

- Are consistent with UK radioactive waste disposal policy.

The necessary research and development as well as the design have all been carried out in-house.

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