AN INTEGRATED APPROACH TO RADWASTE REPOSITORY DESIGN

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ABSTRACT

The planned UK repository for deep disposal of ILW and LLW requires an integrated engineering design as well as appropriate single-discipline work. This paper refers to four aspects of a recent project in conceptual design of deep repositories.

Waste transport from receipt to emplacement is considered in terms of collating mechanical handling, mining engineering and radiological safety design work. A similar combination applies to the choice of disposal vault form and in-vault handling system.

A special case is the possibility of a dropped load and consequent release in a vault. The design included a wide ranging assessment of possible measures before adopting a ventilation and control arrangement appropriate to the hazard.

The paper concludes with a brief explanation of the planning strategy for the layout of cavern vaults and access facilities.

INTRODUCTION

A repository. particularly a deep mined repository, calls on an unusually wide range of engineering expertise. Whatever the organization of the design team, it is necessary to establish common aims, common priorities, and a way of working which ensures that the design progresses coherently.

A management system based on control of formal information exchanges is one part of ensuring that each discipline is briefed on the requirements of others. However, from the early stages when the most basic design work is being done, a less formal interchange of ideas and analyses is important in order to make progress towards common aims.

The intention of this paper is to show, by the example of the Deep Land-Based Repository Design for UK Nirex Ltd., how the approach has been put into effect by the authors' design team at the concept design stage of the project.

OUTLINE OF THE PROJECT

UK Nirex Ltd. is charged with the development of a single UK repository for the disposal of LLW and ILW (1,2).

In January 1988, UK Nirex asked the Costain-Arup-Electrowatt Consortium to develop conceptual designs for a deep mined repository at each of three representative sites:

- a generic hard rock site;
- a generic sedimentary rock site;
- the existing (BNFL) Sellafield site.

The designs were to be "land-based"; that is, the waste receipt facilities and shaft heads would be on land inland, coastal, or island location although the vaults might be under the sea.

The conceptual design work covered everything within the site boundary, from construction through operation to decommissioning. Resources, costs and operational safety were considered; long term safety was to be confirmed by a subsequent analysis, given the basic feature for conceptual design that the depth and geology provided a suitable far field environment.

The capacity of the repository was to be 50 years' arisings of ILW and LLW, including ILW in store and decommissioning wastes. This amounted to (million m^3):-

	Untreated	Packaged for Disposal
Operational LLW	1.50	1.40
Decommissioning LLW	0.50	0.70
Operational ILW	0.44	0.55
Decommissioning ILW	0.16	0.25
Total:	2.60	2.90

The waste would be delivered in forms ranging from 200 litre drums in conventional ISO freight containers to 65 ton packages of grouted decommissioning wastes.

PACKAGE SIZE

An early consideration was how to send underground the 65 ton packages, 4m long x 2.4m wide x 1.8m high. The basic design is determined by the criteria of rail transport on the UK network and there is a definite economic incentive to make the packages as large as possible.

To accommodate the package and a vehicle, the shafts will need to be 8 meters internal diameter, and the laden cage weight will be approximately 100 tons. The various sites called for depths to vault level of 100 meters (for LLW only) to a maximum of 1300 meters.

The design team considered that, although the requirement was beyond the capacity of any operating mineshaft known to them, it would be achievable by application of existing technology. The shaft safety standards would be those for manriding use in the UK mining industry.

In parallel, the handling systems for the whole site were being developed (3) based on overhead cranes, rail vehicles, and some conveyors, all providing precise remote control. The mechanical handling designers and the mining engineers came together to examine the feasibility of using inclined drifts to reach the underground works, eliminating shafts and the operations of loading and unloading the cages (Fig. 1).

Analysis showed that drifts became progressively less practical with increasing vault depth; one design is based on LLW disposal at 100m depth and drift access has been included in this case. Some detailed design points remain to be resolved in making a rack-and-pinion system adequately reliable for waste traffic. Mining practice conventionally uses conveyors, rubber tyred traction, or rope haulage in drifts but does not favor rack-and-pinion systems. This also relates to the Sellafield situation where one possible vault location is in an area of steeply dipping strata and waste may have to be moved up and down a gradient of 1:6 or steeper.

Having identified the outline of the main waste transit system, the design included more detailed consideration of packaging.

Shaft operations will be slowed down by the need for careful loading and unloading of the cage. The designers therefore agreed to base all site-produced packages on a 65 ton all-up weight limit and a 4 x 2.4 x 1.8 meter size limit or (preferably) module.

These packages are for:

- compacted LLW in a grout matrix;
- transit of operational ILW, delivered already grouted;

the first of which is a comparatively unconstrained design.

However, for ILW, the waste will arrive in thick-walled shielding containers of about 50 tones laden weight, for which the surface dose rate is limited by regulation. Within the repository site, all packages will be handled remotely

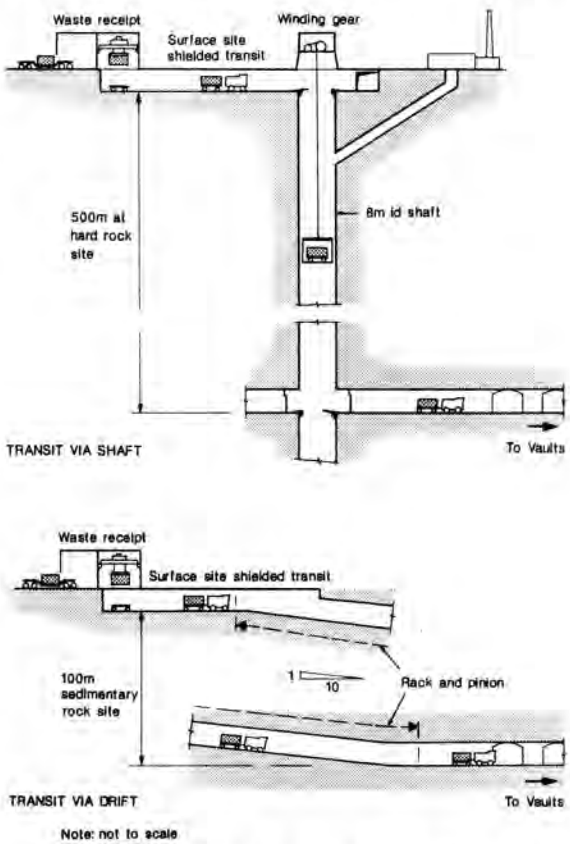

Fig. 1. Shaft and Drift Access.

and therefore the dose rate limit for the public network is not necessarily the relevant criterion.

The design team therefore proposed waste handling routes permanently shielded for the protection of the repository staff, and a "thin-walled" vault shield box with double the payload of a public network container within the 65 ton weight limit, hence half the number of shaft cage loads. The vault shield box will provide sufficient shielding for recovery in case of breakdown.

At their destination, the packages are part of a planned system of filling the vaults and backfilling the waste stack. Whether the vault should be deep (e.g. a cavern) or shallow (e.g. a tunnel) is a decision partly dependent on the scheme for putting the packages into their final position. Whether the packages are fitted for fork-lift or for trunnion pick-up cannot be separated from vault design.

VAULT DESIGN AND VAULT HANDLING

The design team put forward eight types of vault, not all of which could be used in all geologies. Each type was considered in terms of what handling equipment could be used in it, thus (Fig. 2):

Vault Type	Preferred handling system	Option for handling system
Cavern	Overhead crane	Fork lift on waste stack*
Silo	Overhead crane	Fork lift on waste stack*
Tunnel in rock	Fork lift	Straddle carrier
Block and pillar mine	Fork lift	Straddle carrier
Tunnel in clay	Special trolley for packages, emplacement machine for drums	
Inclined drift	Fork lift on stacked waste*	Straddle carrier
Chutes	Special hoist and release mechanism	
1 metre boreholes	Special hoist and release mechanism	

* Note: These systems rely on the fork lift vehicle running on a backfilled waste stack, and a further transfer device to deliver the waste packages to the right level.

Normal cost evaluation of excavation suggested caverns or silos as the most economical form of construction.

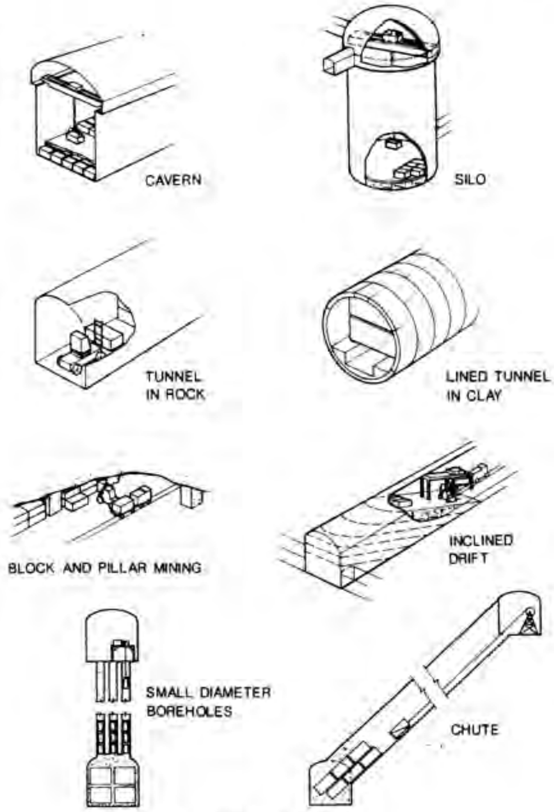

Fig. 2. Vault Designs.

Operational safety criteria effectively required remote control of fork-lift handlers, and uncertainty over the precision of control produced a preference for overhead craneage as in the surface facilities.

For rock environments, the designers' choice was therefore between caverns and silos. The former can be constructed practically to a volume four times the latter, so fewer crane commissioning exercises would be needed. Silos are also unsuitable for strata of limited depth.

So, for all strata except clay/mudstone at the sedimentary rock site, the design team proposed cavern vaults with overhead craneage. Conventional practice is to construct such a cavern as wide as the practicable roof span, and support the crane rails off steel brackets. In the case of the vaults, this would produce dead volume in which waste could not be stacked and for which there was no other use.

The design therefore adopted a cavern section with ledges for the crane rails just below the roof arch springing level.

The design team's approach leads to the cavern design as long as large high vaults can be used, and as long as fork lift handling is unattractive. If the waste stack is not progressively stabilized by backfilling, it may be necessary to restrict the stack height and increase the floor area. It would then be important to minimize unused overhead volume and therefore to re-examine the case for fork lift handling.

In the sedimentary rock site, the ILW disposal stratum is mudstone in which only circular section tunnels, concrete lined, are feasible. In this case it has been necessary to propose a series of special handling devices, such as an emplacement machine for 500 litre drums of ILW. The likely limit to vault tunnel diameter of 5 meters will be a tight constraint on machine design; the design will also have to account for the various demands of waste handling, ventilation and backfilling all at one workface.

The integrated design of the tunnel repository layout for construction, waste handling, emplacement, and backfilling is material for a paper of its own.

DESIGN FOR ACCIDENT CONDITIONS

Throughout the repository, a conscious effort has been made to restrict the possibilities for accidents. In particular, serious drops of waste packages have been "designed out" by reducing lift heights, leading to a single-level handling layout on the surface, and another underground.

The nominal possibility of a runaway in shafts or drifts will always exist, but will be mitigated by applying the highest available design/maintenance standards and by including impact limitation measures.

A problem arose when considering cavern vaults since, in order to take advantage of the economy of large excavations, the overhead crane would be between 10m and 30m above the floor depending on the host rock conditions. Partitions within the vaults were considered desirable to limit the volume of backfill to be poured at any time, suggesting the waste packages would be carried at high level before placement.

The probability of an in-vault dropped load is not high, but it is not negligible either. Particularly in the case of operational ILW of which over 200,000 crane loads are to be handled an appreciable release could result in the case of severe, if improbable, impact.

A range of design solutions was proposed, such as (Fig. 3):-

- reverting to fork-lift handling on the stacked waste and delivering the packages to a moving platform at stack level;
- using a long crane cable to move the waste at just above stack level;
- using a long crane cable to move the waste over a ramp down to stack level;
- building cells in the vaults and lowering waste loads under a hood completing local containment;
- reverting to tunnels and fork lift handling;
- overpacking all wastes sufficiently to provide impact protection;
- providing ventilation and access control, with facilities to recover from an in-vault release.

Each solution had to be judged on its merits as a way of improving safety to a degree which justified the cost. The handling system design would be based on high integrity equipment, interlocked lifting features, and rigorous monitoring. The vault itself would be a contained environment without anyone working in it.

The design solution which most effectively eliminated the hazard, at a level appropriate to its assessed severity, was to adopt the cavern vault design with ventilation and access control.

Ventilation facilities have therefore been identified for each vault with filtration and control standards appropriate to the wastes in the vault. Air drawn from vaults in which waste has been placed will be discharged along a dedicated tunnel and by an upcast shaft (used for waste traffic) to a stack, without any operator exposure during normal working.

UNDERGROUND LAYOUT

Preliminary analysis of the repository activities showed no advantage in phasing construction of vaults separately from waste disposal operations. Carrying on both simultaneously requires rigorous segregation and shielding, but in underground workings both can be readily achieved.

The underground layout (Fig. 4) was largely determined by waste handling considerations, although rock mechanics dictated that the cavern long axes should all be parallel to the maximum in-situ stress and hence to one another.

The cavern length was set at 250m in order to limit the crane cycle time from pick-up to set-down and return. Waste delivery from the shafts to the vaults was allocated to a

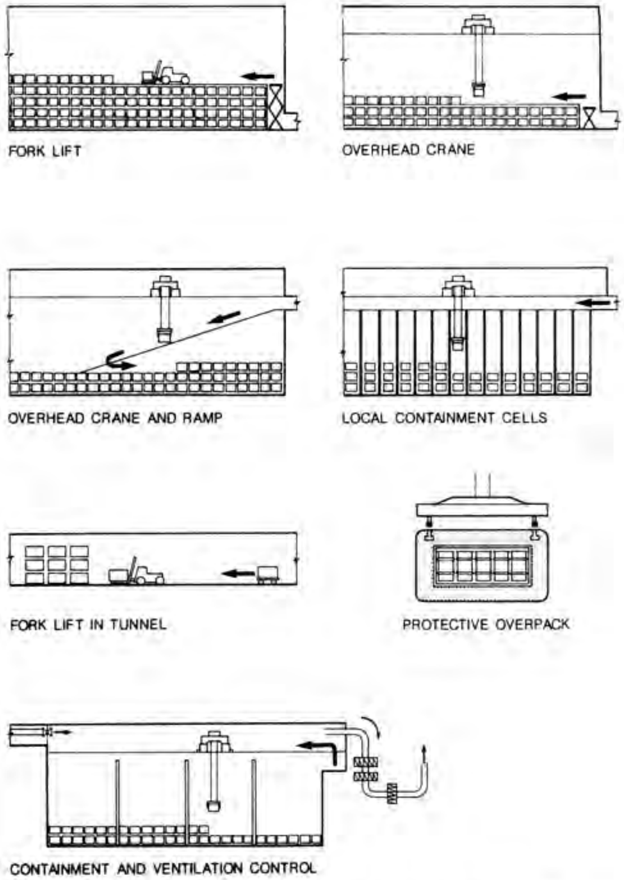

Fig. 3. Design Against Dropped Load Accidents.

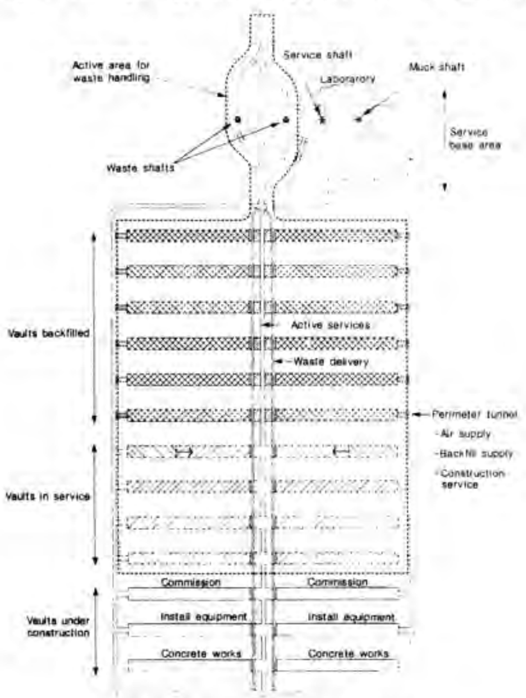

Fig. 4. Underground Layout.

"spine" to minimize haulage distances and the size of the most closely controlled zone.

This spine also houses the "active" air extract tunnel and, above it, a service tunnel providing access for crane maintenance, filter changes and all "active services". This tunnel also allows the vault cranes to be brought out through the maintenance bay and moved down the spine to the next vault.

This tightly defined spine leaves the far ends of the caverns available for supply of backfill a major operation, equal in volume to the deposition of waste packages at the cavern roof level. During construction of a cavern this high level entry, and a floor level entry below it for muck haulage, are the contractor's access points.

The tunnel linking the outer ends of caverns has a number of important functions:-

- backfill supply
- construction traffic and services
- air supply "ring main"
- geological proving survey.

This last is in fact the first in time: driving the perimeter tunnel proves the quality of the rock for the vault area as a whole.

In order to limit the extent of surface works, all the shafts for the repository are close together. Two are allocated to waste handling and are therefore on the extended "active" spine. The other two are for non-active traffic and are linked to the perimeter tunnel which is the main service circulation.

The underground depot areas are laid out broadly on a radiological grading; the area closest to the active spine is reserved for waste haulage locomotive maintenance and a crane maintenance base, both of which may need decontamination facilities. Further away are the contractor's depot, which is non-active, and an underground laboratory.

CONCLUDING COMMENT

By examples from the deep repository design, the authors have tried to show how certain aspects of the project have been approached on a multi-disciplinary basis and therefore have, at a fundamental, a coherence of design. Some aspects have not been described, for example the layout and planning of the tunnel repository, or of the surface site. In both cases, and elsewhere, the design team has tried to pursue safety, economy, and practicality as aims in a single design, however many engineers and disciplines may be needed to carry out the work.

ACKNOWLEDGEMENTS

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