Large Shielded Packages for Decommissioning Waste

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INTRODUCTION

Following earlier work (Price and Lafontaine, 1985) a further study of large shielded packages for decommissioning waste was initiated in September 1986, funded in part under the second five year joint action programme of the Commission of the European Communities (CEC). A methodology was developed which considered all the factors and constraints affecting the design of a package over its total life-cycle.

It involved five interactive tasks, viz:

A the effect of manufacture on design of large transport packages for decommissioning waste;
B a survey of transport hazards and constraints;
C the constraints of disposal on package design;
D package design/performance criteria; and
E the assessment of proposed package designs.

The investigations were carried out jointly by the Winfrith Technology Centre (WTC), Ove Arup and Partners (OAP) and Windscale Laboratory (WL), with the Safety and Reliability Directorate Culcheth (SRD), acting as consultant, and a comprehensive report on the work is in preparation.

The status of decommissioning operations in the Federal Republic of Germany (FRG), France and the United Kingdom (UK) was established as these countries have large civil nuclear power programmes in the European Community.

Initially the factors affecting package design were examined. The study of large reinforced concrete packages was led by the Windscale Laboratory, which is already involved in the decommissioning of the Windscale Advanced Gas-Cooled Reactor. The work on ferrous packages was led by WTC. Task B, carried out by OAP, involved desk and route studies of transport hazards as well as the definition of regulatory and physical constraints. Reference routes in the FRG, France and the UK were selected for detailed survey. This gave an estimate of accident probabilities for ten transport accident scenarios. In carrying out Task C the following aspects were examined by WTC:

i the radionuclide inventory required to be disposed;
ii the estimation of the toxicity of the leachate from packages;
iii disposal implications of the radionuclide inventory;
iv the constraints imposed by disposal sites;
v the effect of cement formulation on the migration of key radionuclides;
vi the corrosion behaviour of ferrous metals; and
vii gas production from a package.

Tasks A, B and C were data collection tasks which fed into the two final tasks of the study, Package Design Criteria and the Assessment of Package Designs, led by OAP.

OVERVIEW OF DATA COLLECTION TASKS

WASTE INVENTORY

The majority of the radioactive waste from PWR's, BWR's and gas-cooled reactors will fall in the low level and ultra low level waste categories, ie outside the scope of the study, because it does not require shielding. Most of the remainder is suitable for transport as a Type 2 Industrial Package (using the terminology of the IAEA Transport Regulations (Safety Series 6)). The amount of waste requiring transport in a Type B package will diminish with time. Economic factors are likely to lead to long delays in carrying out Stage 3 decommissioning so that the arguments in favour of developing special Type B packages are likely to be marginal and existing Type B containers might be better. For this reason the present study has concentrated on Type 2 Industrial Packages.

CONTAINER MANUFACTURE

FERROUS METAL

Although more expensive than concrete, the advantages of greater density, improved impact performance and tensile strength, straightforward quality assurance methods and ease of decontamination make ferrous metals very worthy of consideration. The type of ferrous metal selected is linked to the methods of construction adopted. The choice will also depend on the variations in material properties and the overall dimensions of the required package, especially the wall thickness to length ratio. From a shielding point of view, a minimum package wall thickness of around 30 mm is required.

The methods of fabrication considered and commented on in the Semi-Annual Progress Reports (Price, 1988) are:

a) welding of plate;
b) casting in spheroidal graphite cast iron;
c) forging; and
d) casting of steel.

These have been examined against the requirement as a result of which it has been concluded that for this case a decommissioning waste package can be constructed in ferrous metal and that either welded plate fabrication or SGI casting are appropriate construction methods.

CONCRETE

The influence of construction methods on the design of reinforced concrete packages has been discussed in Semi-Annual Progress Reports from this study (Price, 1988) the subjects examined being package shell manufacture, types of cement, types of concrete, reinforcement, grouting, lid placement and final closure. The overriding consideration in manufacture is cost. Reinforced concrete is a cheap and plentiful material, which can provide the structural integrity required of an Industrial Package. For very thin-walled construction the novel use of sprayed fibre-reinforced concrete is proposed.

LIFTING FEATURES

Various lifting methods had been proposed for the 50 t Windscale Advanced Gas Cooled Reactor (WAGR) decommissioning waste package. The initial proposal was to incorporate large steel lifting lugs cast into the package walls. On cost, long term integrity and storage density grounds, the large lifting lug design has not been advocated for this study. In self shielded concepts the exterior of the package can be completely featureless, with spacers used between packages, so that they can be lifted from the base. With a returnable shield the outer (returnable) shield can be fitted with ISO corner fittings and grappler lifting pockets. The concrete disposal package carried within the outer shield, as with the self shielded concepts, has no external lifting features and is designed to be lifted from the base.

TEMPORARY STORAGE

To avoid unacceptable degradation during storage the package design must be compatible with the storage conditions. The obvious constraints are corrosion protection of ferrous components and the prevention of water entering the package and leaching out radionuclides. Other considerations are the ability to inspect the packages periodically and the stacking height adopted. At the end of temporary storage the package must remain intact for handling and transport to the disposal site. Packages could be stacked up to six high in a temporary store. This imposes compression strength and stacking stability requirements on the package.

TRANSPORT

The choice between the modes of transport will depend on the actual sites of the power stations and the disposal site and the possible modes of transport between them. Where suitable dock facilities are available the use of marine transport should be considered, though some transport by road or rail is still likely to be needed.

If road travel were found to be preferable then the greatest flexibility would be obtained by adopting a 25 t gross weight package so that standard vehicle types could be used. In Western Europe the rail network is highly developed so that advantage can be taken of the carrying capacity of rail transport. A large package can easily be handled with the attendant advantage of a higher ratio of waste volume to overall package volume. It was concluded therefore that the studies should concentrate on a package with a gross weight of 65 t, transportable on a standard 4-axle wagon. Although a package of nearly twice this weight carried on an 8-axle wagon was considered, difficulty of handling led to it being ruled out.

Mandatory requirements for Type 2 Industrial Packages are set out in the IAEA Transport Regulations (Safety Series 6). A Type 2 package of mass >15 t must undergo a stacking test in which the package is subjected to a compressive load of five times its own weight, as well as a free fall of 0.3 m onto an unyielding target in which the package must retain its contents and not lose more than 20% of its shielding. Use of rail transport brings with it the further requirement of compliance with the appropriate rail gauge.

In the course of the work, desk and route surveys of hazards were carried out which led to ten postulated transport accident scenarios in which a package could be damaged through impact or fire. The frequencies of occurrence of these scenarios were then estimated using accident data from railway operations in the FRG, France and the UK.

DISPOSAL

The repository in which the waste is finally disposed can impose various constraints on package shape, size and weight as well as on the allowable surface dose rate. Reception and emplacement at the disposal site imply a variety of possible handling incidents. Designs of disposal site for intermediate level waste are in the evolutionary stage and the constraints on package design are not yet fully defined. Unless there is a pre-existing constraint on weight and dimensions, as for the Konrad mine in the FRG, it can be anticipated that packages up to 65 t will be able to be handled.

In general the aspects to be considered in studying the effect of disposal on design i.e., site restrictions, cement formulation, ferrous metal performance, radionuclide inventory and its radiological impact will have a low influence on design of the waste package. There will be gas production from degradation of waste and corrosion of package materials. However, such gas production will be only part of the total gas evolution, because of the large amount of steel reinforcement inherent in the construction of the repository. Estimates of the amount of gas evolution within a package indicate that in the case of a clad package pressure build-up is likely to be unacceptably high unless the system is vented. Unclad concrete packages will possess sufficient permeability to allow gas release.

DEVELOPMENT OF THE PACKAGE SPECIFICATION

The specification which was developed includes both "mandatory" requirements and design targets for packages.

In reality the only truly "mandatory" requirements are those invoking compliance with regulations. However other requirements are likely to be imposed and are therefore for the purpose of this paper also classed as "mandatory". The list of those requirements covers:

a) compliance with IAEA Transport Regulations for a Type 2 Industrial Package;
b) maximum weight of any individual waste item;
c) maximum package weight;
d) external shape, compliant with the Railway Gauge;
e) venting; and
f) maximum storage period prior to disposal.

In addition to the so-called "mandatory" requirements a set of design targets was laid down with the aim of exploring safety margins. The concept of design targets is not meant in any way to undermine the paramount nature of the IAEA Transport Regulations.

PRELIMINARY "MINIMUM" PACKAGE DESIGN CONCEPTS

In the final part of the study the package specification was used to develop conceptual designs. Manufacture in various types of concrete and ferrous metal was considered. Rather than elaborate one design in great detail, a number of concepts was developed, all of which satisfied the mandatory part of the specification but which met the design targets of the second part to a greater or lesser degree. In this way, the costs of providing various degrees of enhanced package performance were investigated and some guides to cost/benefit were derived. Broadly speaking, there are two main categories of design viz: a self-shielded (SS) package, disposed of in its entirety or a package with returnable shielding (RS).

The main features of the five designs which were evolved are summarised below. The method of designating the various concepts is as follows: the first two letters, either SS or RS, indicate whether the package is self-shielded or has returnable shielding; the following six numbers indicate the shield thickness - the first three the thickness of concrete in mm, and the second three the thickness of steel in mm. A novel feature of the RS 075/008 design is the use of fibre-reinforced sprayed concrete to manufacture the thin (75 mm) walls of the internal disposable package.

Design Concept	Overall Dimensions (mm)	Volume to be Disposed (m^3)	Weight of (steel) Waste (t)	Comments
SS 100/000	2400 x 1850 x 4550	20.2	30.05	Base thicker at 150 mm to sustain lifting from base.
SS 075/008	2400 x 1850 x 4300	19.09	30.52	Cladding used as a shutter for the concrete. Lifted from base.
SS 000/030	2400 x 1850 x 3800	16.87	30.36	No external handling features. Lifted from base.
RS 075/008	2400 x 1850 x 5100	18.61	28.58	Outer container fitted with handling features. Internal disposable package dimensions 2260 x 1600 x 4960 mm has no external lifting features.

The comparative costs of the above concepts have been evaluated based on a decommissioning inventory deliberately simplified to be 600,000 t of steel waste. The results for a range of disposal costs are:

Design Concept	Disposal Cost (£/m^3)			
	600	1400	2500	7000
SS 100/000	281.1	603.7	1047	2862
SS 075/008	312.2	612.5	1025	2714
SS 055/015	361.4	652.2	1052	2688
SS 000/030	482.9	749.6	1116	2617
RS 075/008	287.5	600.0	1030	2788

NOTE: These comparative costs (in £ million) are the costs of aspects of the total decommissioning cost which vary from concept to concept; ie package manufacture, transport, disposal and total number of packages.

Insensitivity to variation in disposal cost is an important factor in selection of a "minimum" design when disposal costs (of what is termed Intermediate Level Waste in European countries) are not yet confirmed. In Figure 1 the cost sensitivity is indicated by the gradients of the curves for each concept; less steeply sloped curves are less sensitive to disposal cost.

For such a situation the RS 075/008 concept has the following advantages:

a) provision of an external surface which is easily decontaminated;
b) easier maintenance of the returnable shield;
c) providing greater impact protection;
d) standard lifting features can be employed;
e) it is flexible to changes in requirements; and
f) if waste has to be stored for an extended period the shielding thickness can be adjusted to be suitable at the time of transport.

The use of sprayed concrete to make the thin-walled inner disposable container is novel and an important element in the economics of the RS 075/008 design.

DESIGN FOR ENHANCED PERFORMANCE

Consideration has been given to the achievement of enhanced performance in the form of additional (extra-regulatory) impact resistance, resistance to fire and/or improved radiological performance. Figure 2 shows the relative cost of achieving improved impact performance for SS and RS concepts for a constant disposal cost of £600/m^3. It can be seen that the RS concept is the cheapest way of achieving enhanced impact resistance, further underlining its validity.

CONCLUSIONS

The main results of a study of the design of large shielded packages for the transport of intermediate level waste from the decommissioning of nuclear reactors are reported. The study, which was funded in part by the CEC, concentrated on the design of Type 2 Industrial Packages and was based on a design methodology which took account of the various manufacturing, handling, transport and disposal constraints over the total life cycle of a package.

Both self-shielded and returnable shielded concepts were developed. For the particular example studied, the principal conclusion is that a large returnable shielded concept containing an internal disposable package and an all-up weight of 65 t provides a robust design solution for organisations which wish to proceed with immobilisation. This concept is relatively insensitive to changes in disposal costs and much more easily adaptable to comply with enhancements in performance under fire and impact accident conditions than an optimised self-shielded reinforced concrete package.

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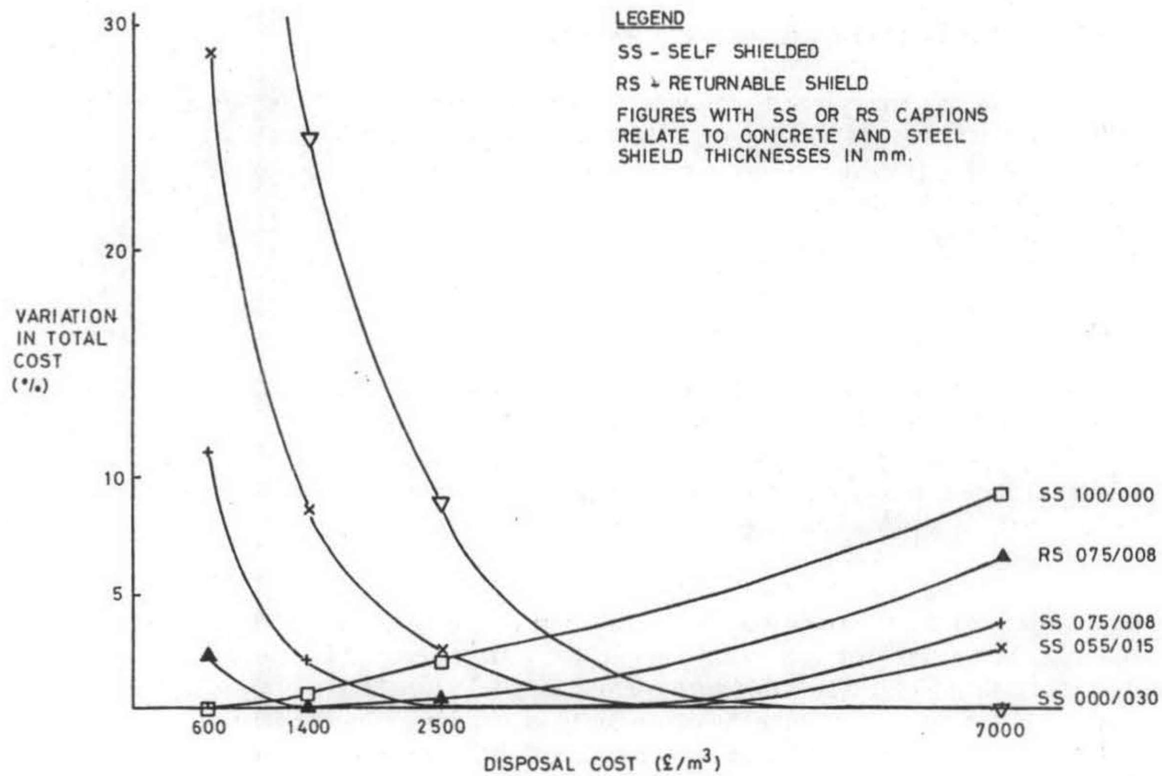

FIG 1 RELATIVE COST AS A FUNCTION OF DISPOSAL COST

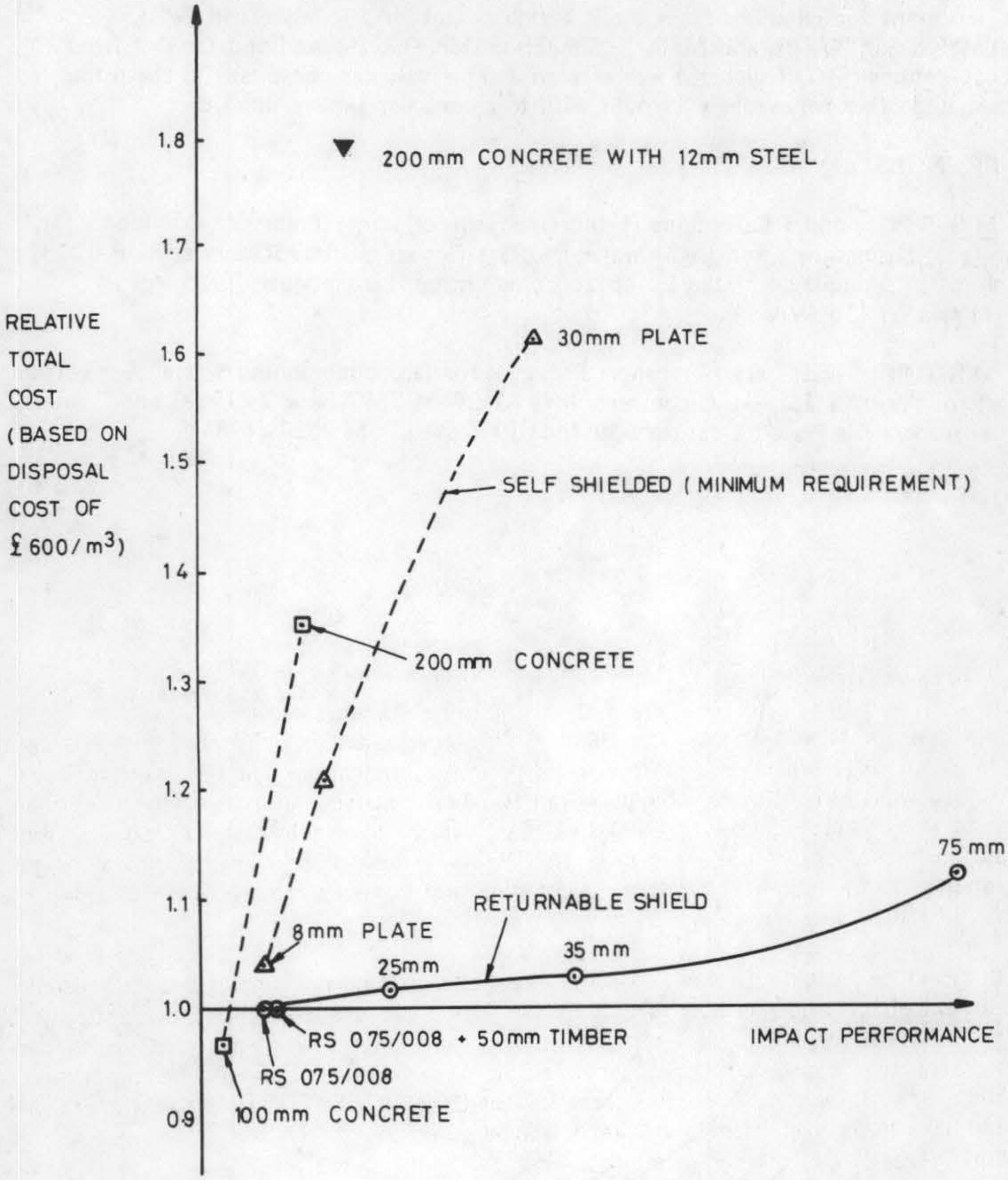

FIG 2 RELATIVE COST OF ENHANCED IMPACT PERFORMANCE (BASED ON DISPOSAL COST £600/m³)