The Development of Transport Container Designs for Immobilised Intermediate Level Waste

M.J.S. Smith[1], R.W.T. Sievwright[1], B. Marlow[1], P. Donelan[2], J. Miles[2]

[1]*UK Nirex, Ltd., Oxfordshire*
[2]*Ove Arup and Partners, London, United Kingdom*

1.0 INTRODUCTION

This paper describes the work undertaken by UK Nirex Limited to develop a range of containers for transporting immobilised intermediate level waste (ILW) from the site of arising to a repository for disposal. In the UK, ILW is defined as waste having greater than 4 GBq/tonne alpha activity or 12 GBq/tonne beta/gamma activity but excluding the high level waste which arises from the reprocessing of irradiated fuel, generates heat and will be vitrified. The latter is to be stored for at least 50 years to allow the heat emanating from it to diminish before disposal.

For ILW, storage offers no advantages. The principal method of packaging the waste for disposal will be to immobilise the material in a cementitious matrix which will then be contained in a high integrity 500 litre steel drum. For larger items of waste which will not fit within a 500 litre drum, a $3m^3$ steel box will be used. A typical drum and box are shown in Figure 1.

The drums and boxes will be transported from the site of arising to the repository in a returnable steel transport container. Each container will carry either four 500 litre drums or one $3m^3$ box, and will provide protection and additional containment for the contents as well as providing shielding (Ref. 1).

To provide one shielding thickness for all wastes would be uneconomic because extra weight would have to be transported in most cases. Therefore it is envisaged that four shielding thicknesses will be used with the maximum thickness being 300mm, but this is currently under review.

Work completed to date on the design of transport containers has led to the development of three conceptual designs (Figure 2). Each concept has been designed to accommodate the same payload and each has been demonstrated to meet the preliminary design criteria laid down by UK Nirex Limited. The methods employed to develop and justify these designs are described in the following sections of this paper.

Ultimately, it will be necessary to operate a fleet of transport containers comprising some 300-400 units. Some consideration has been given to the most efficient means of manufacturing these designs and the paper concludes with a short discussion of the available options.

2.0 PERFORMANCE EVALUATION

Assessments of mechanical and thermal performance have been carried out for both normal and accident conditions of transport. The criteria adopted in these evaluations have been based upon the IAEA Type 'B' regulations. In some cases, these have been augmented by self-imposed standards, designed to explore the margins which might reasonably be achieved in the spirit of the ALARA principle. These included a 36m drop onto a rigid target after which the shielding was to remain intact.

For the purposes of clarity, the methodology employed in the performance evaluations is described below by reference to one design concept only. (Figure 3). However, it should be noted that these procedures have been applied to all three concepts shown in Figure 2.

2.1 Impact Integrity

Preliminary scheme designs were developed on the basis of hand calculations as described in Refs. 2 and 3. These calculations were sufficient to establish the broad viability of the basic concepts, but were not sufficient to confirm whether or not the containers would meet the specific design criteria.

Demonstration of performance comprised firstly a detailed justification of the design by calculation and, secondly, a series of physical tests on $\frac{1}{4}$-scale models.

Detailed impact calculations were performed using the computer program OASYS DYNA3D. A typical finite element mesh is shown in Figure 4(a). It should be noted that the model was sufficiently detailed to include the drums, a stillage for handling the drums and the transport container as separate parts. Particular care was paid to the lid/body interface zone. This level of detail was considered essential for a proper evaluation of lid retention and sealing.

Working from the preliminary concept which had been defined by hand calculations, a series of design iterations was carried out using the computer models. This led to the production of the final detailed design. Drawings were then produced for the manufacture of $\frac{1}{4}$-scale models and test prototypes were procured.

The design target was well beyond previous experience. Not only was the 36m drop much greater than the normal design condition, but the mass ratio of contents/container (sometimes in excess of 1:1) was much greater than the norm for irradiated fuel cask design in the UK (typically 1:20). This meant that the inertia load of the contents was very significant and it had a considerable influence on the design for lid retention in lid-down impact attitudes. The extreme case was represented by a heavily loaded $3m^3$ box (15 tonnes) packed within the lightest transport container (12 tonnes). Under these circumstances, the inertia load delivered by the contents to the underside of the lid became too great and it needed to be reduced. A special internal shock absorber was introduced between the top of the box and the underside of the lid in order to remedy this problem, Fig 4(b). A considerable amount of attention was also paid to the design of the $3m^3$ box itself, ensuring that no aggressive features on the exterior surface would lead to puncturing of the box skin during impact.

The impact tests were carried out using a standard IAEA target. The model container was guided in its descent so that a high degree of accuracy could be ensured with regard to impact attitude. Transient recordings of acceleration and bolt stretch were taken from accelerometers and strain gauges. Permanent damage was deduced from extensive metrology carried out before and after each test. The experimental methods employed followed the practices described in Ref. 4.

The entire design process, from initiation to successful demonstration using scale models for all three concepts, was accomplished in less than 18 months. This could only have been achieved by taking care to get the design "right first time" thus removing the need for the expensive and time consuming design iterations which would have been necessary had the first test been unsuccessful.

2.2 Thermal Integrity

Having established the transport container design on the basis of mechanical requirements, a study of the thermal performance was undertaken. Once again the design criteria adopted were firstly to meet the requirements of the IAEA Regulations and secondly to study the performance margins beyond the regulatory requirements.

The payload of the containers comprises radioactive materials immobilised in a cementitious matrix, and contained in high integrity steel drums or boxes. As a result, the thermal system is complex and involves a series of discrete bodies with gaps between them. In addition, attention must be paid to the formation of steam in the cement if temperatures exceed 100°C.

Preliminary heat transfer studies were carried out using a simplified one-dimensional model. A series of 'ranging' calculations was undertaken in which the IAEA fire test for a Type 'B' package and several conditions representing "real" fire scenarios were explored. The latter conditions were based upon data obtained from an extensive survey of railway accidents carried out in the UK several years before (Ref. 5) and, broadly speaking, covered fires burning for a longer period of time than the IAEA test, but with less severe conditions of engulfment. Naturally, there was a degree of uncertainty associated with some of the input conditions and physical properties of the system but, because of their simplicity, the 1-D model was ideal for carrying out rapid sensitivity studies and for obtaining a better understanding of the system response.

The one-dimensioned studies concentrated purely on limited spatial and temporal temperature distributions. Thermal distortions occurring at the lid to body interface also needed to be addressed in order to investigate the containment capabilities of the designs. For this reason, a more complex series of 3-D finite element calculations was carried out in which the full geometry of the containers was modelled. The finite element models were very similar to those generated for the impact calculations (Fig. 5(a)) and a typical plot of results showing thermal distortions, exaggerated for clarity, is presented in Fig. 5(b).

The most important conclusions drawn from the thermal studies were:

i) The limited thermal capacity of the thinner-walled designs could allow undesirable temperature excursions to take place within the payload.

ii) The distribution of temperatures in the container lid/body interface zone could, under certain circumstances, be sufficient to cause thermal degradation of an elastomeric seal.

iii) The thermal distortions (gaps) arising in the region of the lid/body interface could be sufficient to compromise the seal.

For these reasons, attention has been directed towards the provision of additional insulation particularly in the lid/body interface region. Calculations have shown that, in principle, it will be possible to provide sufficient insulation to ensure that all of the shortcomings outlined above can be remedied. The various practical means for achieving these goals are currently under review.

2.3 Containment and Sealing

Intermediate level wastes will be contained as a stable cementitious monolith in high integrity drums. UK Nirex Ltd is undertaking major programmes of work to investigate the containment that these will provide. These include the quantity of fine particles which can be generated under impact conditions, the likelihood of breaching the encapsulating drum or box, and the behaviour of immobilised wasteforms when heated.

The first programme of work is an examination of the break-up of the matrix and the integrity of 500 litre drums under impact conditions. So far, this work has shown that only a very small fraction of the particles generated fall within the respirable range ($< 20\ \mu m$) and that, due to the robustness of the drum/ wasteform combination, even this small fraction is unlikely to be released (Refs. 6, 7).

In the second programme of work the behaviour of wasteforms under fire accident conditions is being investigated. Where temperatures in the wasteform exceed 100°C, consideration is being given to the possibility of activity release due to steam generation. This is being investigated experimentally for a number of representative wasteforms.

Because of the good containment provided by the drum and wasteform combination, the need for a transport container sealing system is questionable. The data generated so far has indicated that the containment requirements of the IAEA Regulations could be met by the properties of the drummed wasteform alone, without taking into account any contribution from seals provided within the transport container itself.

3.0 MANUFACTURE

The options for manufacturing the transport containers include forging, fabricating, and casting. About 300 will be needed by the beginning of repository operations (targeted for 2005). The lightest design with the thinnest walls weighs in the region of 12 tonne (unladen) while the heaviest weighs in the region of 60 tonne. Forging is an attractive and well tried method for the heavier designs, (although it is expensive). It is not well suited to the thinner-walled designs. The reverse is true for fabrication, in addition to which there are some drawbacks regarding the impact integrity of welds and other connections. Of the three processes, casting is the only one which can reasonably be applied to all types of container. Indeed, because of the rather complex shapes involved, casting is arguably a preferred method for both light and heavy designs. Sufficient work has been carried out to establish that casting is both feasible and economically attractive and a programme of work is being planned in which the relative merits of cast steel and cast iron will be investigated. This programme will generate materials data and will also include an examination of the influence which production methods will have on the selection of the preferred final design.

4.0 CONCLUSIONS

Three transport container concepts for drummed intermediate level waste have been produced and shown to meet the design criteria. Work is now in hand to select a favoured design. Casting is being considered as a method of manufacture.

5.0 REFERENCES

1. Smith M.J.S. The Packaging and Transport of Radioactive Wastes. The Nuclear Engineer. Vol. 29 No. 2 March/April 1988.

2. Dallard P.R.B. "Flask Analytical Studies", Paper 5 from the Seminar "The Resistance to Impact of Spent Magnox Fuel Transport Flasks", Joint I.Mech.E/BNES Seminar, London, May 1985.

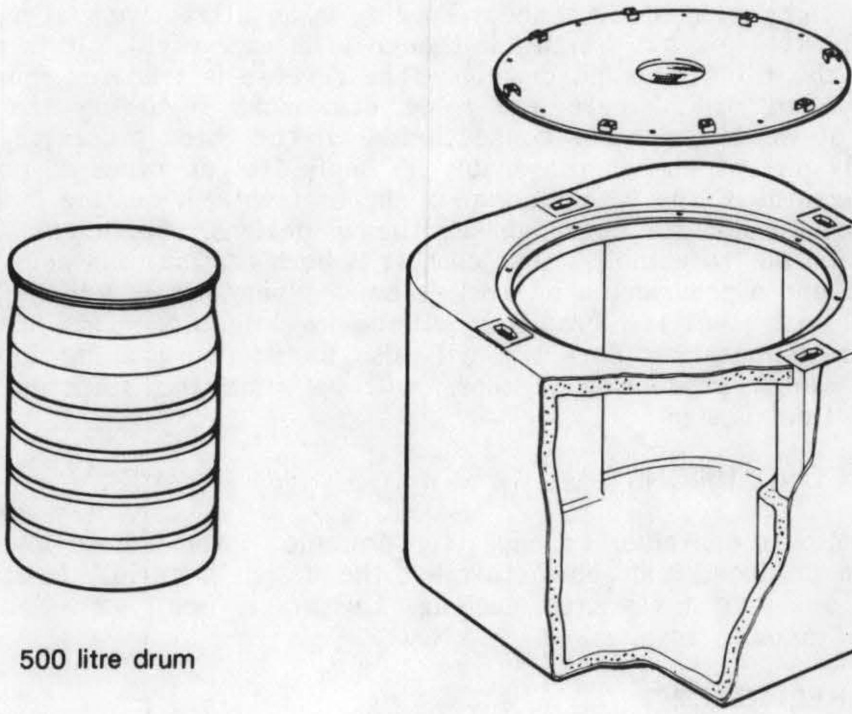
3. Keene R.F. et al. "The Design of Transport Containers for Radioactive Waste Materials", Int Conference on Transportation for the Nuclear Industry, I.Nuc.E, Stratford-upon-Avon UK, May 1988.

4. Morse J.E. and Wilkinson A. "Drop Test Facilities", Paper 6, Joint I.Mech.E/BNES Seminar, ibid.

5. Jones et al. "Real, as Opposed to Regulatory, Conditions" PATRAM 1986 Davos, Switzerland.

6. Nirex Report No. 68. Impact Behaviour of 500 Litre Intermediate Level Waste Drums: II - Fundamentals of Impact Behaviour, 1989.

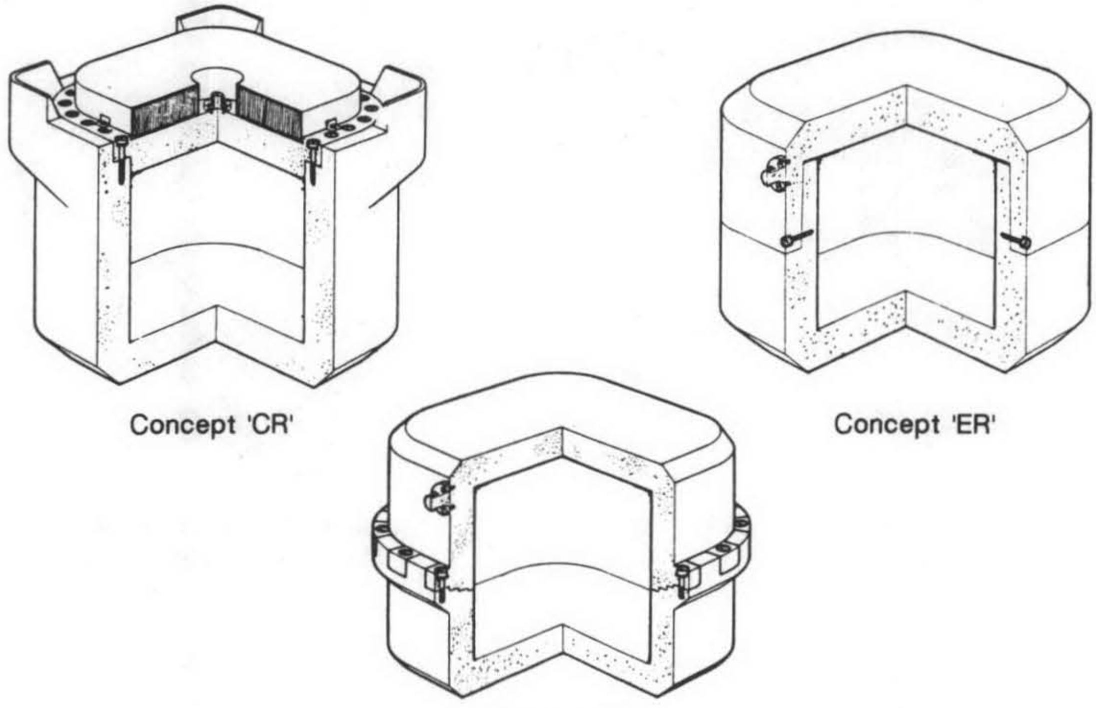
7. Nirex Report No. 69. Impact Behaviour of 500 Litre Intermediate level Waste Drums: III - Behaviour of the Waste Matrix, 1989.



500 litre drum

3m^3 box

FIG. 1 ILW STANDARD PACKAGES



Concept 'CR'

Concept 'ER'

Concept 'OR'

Fig. 2 TRANSPORT CONTAINER CONCEPTS

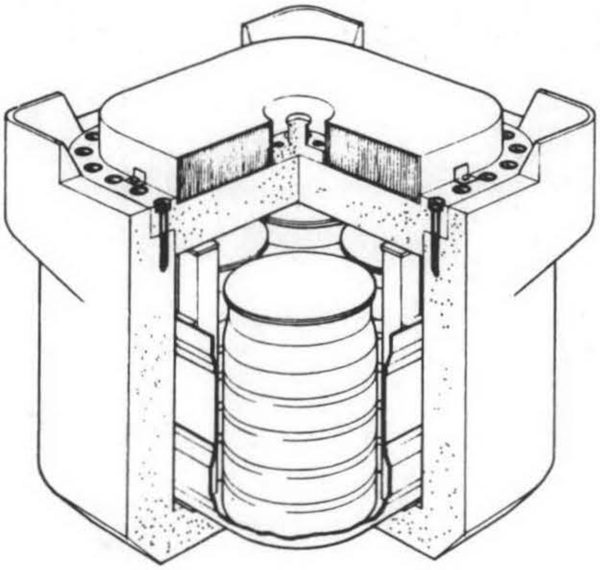
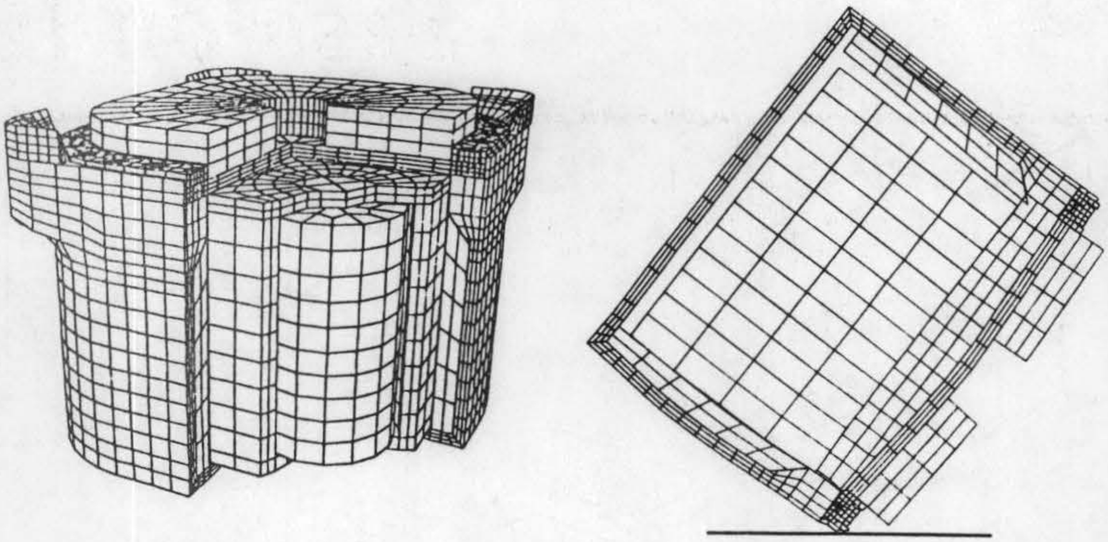


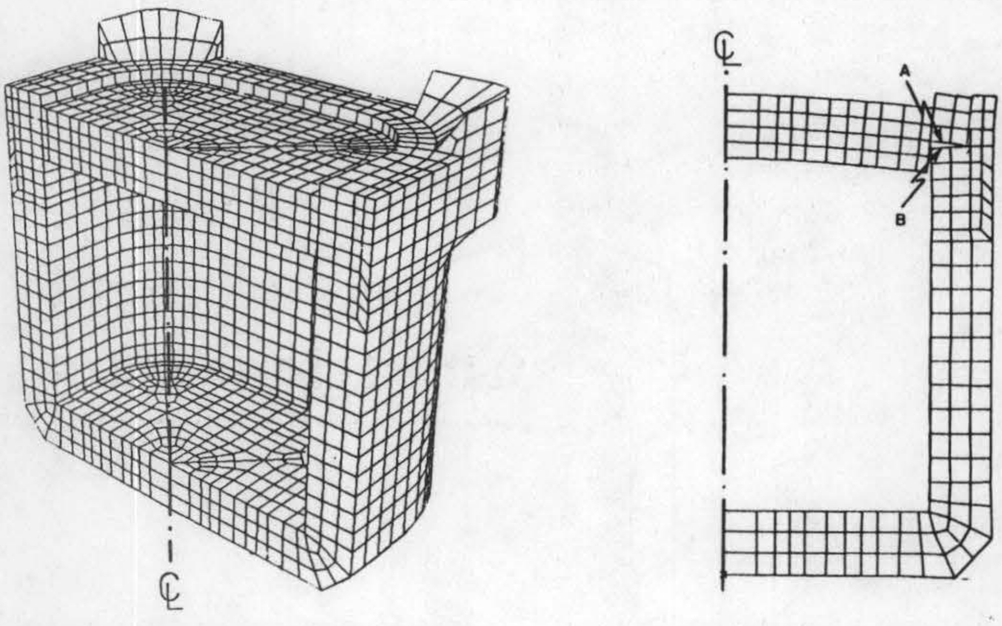
Fig. 3 CONCEPT 'C' LOADED WITH 4x500 LITRE DRUMS



a) Undeformed Mesh (thin-walled variant; contents included)

b) Deformed Cross-Section (lid edge impact)

Fig. 4 FINITE ELEMENT MODEL FOR IMPACT ANALYSIS



a) Undeformed Mesh : (Thick-walled variant; contents omitted for clarity)

b) Deformed Cross-Section

Fig. 5 FINITE ELEMENT MODEL FOR THERMAL ANALYSIS

Session II-3

Package
Content
Characterization