Thermal Analysis of Reusable Shielded Transport Containers for ILW

I.L.S. Gray, R.W.T. Sievwright
UK Nirex Ltd.

P. Donelan, F. Ajayi
Ove Arup & Partners

INTRODUCTION

UK Nirex Ltd is developing a deep repository for the disposal of intermediate level and some low level radioactive wastes (ILW and LLW). Nirex is also responsible for producing standard designs of containers for the transport of waste to the repository. One concept under consideration is the Concept L reusable shielded transport container (RSTC) which is being designed to IAEA Type B requirements (IAEA 1990). The contents of an RSTC will normally be cemented ILW in either four 500-litre drums, or a 3m^3 box or drum of similar outside dimensions to the four 500-litre drums in their transport frame. The RSTCs will be produced in a range of shielding thicknesses from 70mm to 285mm, to suit the requirements of the different waste streams. Figure 1 shows the 70mm version (RSTC-70) and Figure 2 shows the 285mm version (RSTC-285).

The main features of the designs are as follows:

- The lid is retained on the body by lid retaining chocks.
- The sealing function is provided by a lid seal member (LSM) which is clamped to the body and is independent of the lid.
- Impact resistance is provided by integral solid metal flow shock absorbers on the four top corners of the body. Other shock absorbing features for lid-down impact attitudes include a stainless steel-clad wooden shock absorber on the top of the lid, and an under-lid shock absorber to limit the force of the contents on the lid.
- The current design includes an intumescent coating on the outside of the RSTC to provide fire resistance. Nirex is also considering other thermal insulation materials.

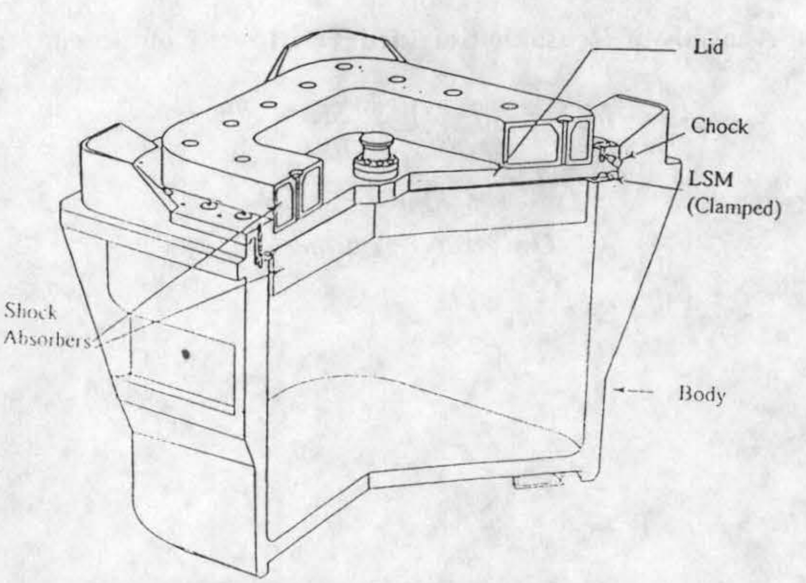

Figure 1. The 70mm Concept L RSTC

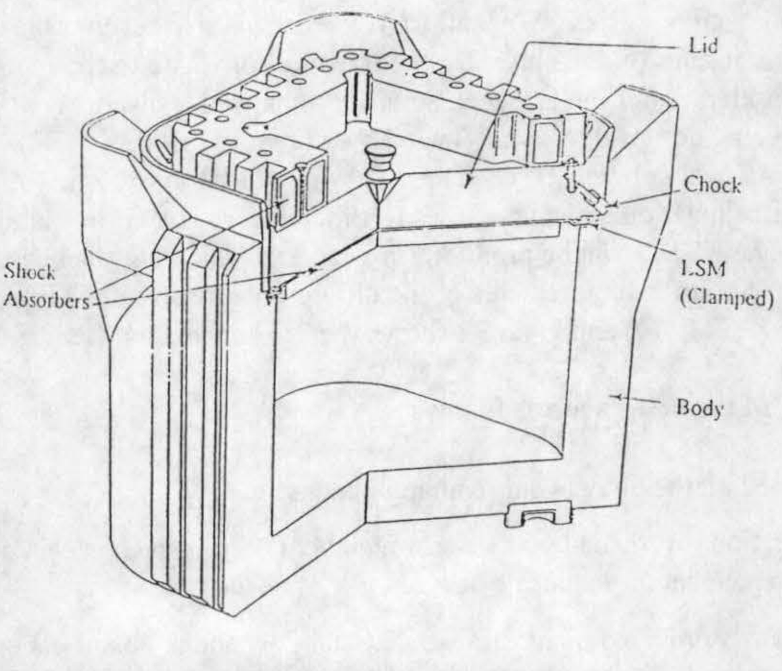

Figure 2. The 285mm Concept L RSTC

Various aspects of the design have been described in detail elsewhere (Sievwright et al. 1991; McKirdy et al. 1994). This paper presents the analysis carried out to demonstrate the performance of the RSTC during the fire test specified in the IAEA Transport Regulations (IAEA 1990).

SCOPE OF THE ANALYSES

The purpose of the work described was to obtain all the data on thermal performance needed for an application for Type B approval. Hence the analyses performed included:

- Determination of steady-state temperature conditions in the RSTC under the IAEA specified ambient conditions for a Type B(U) package (+38°C plus specified solar radiation input).
- An impact analysis to obtain the deformed geometry of the RSTC prior to the start of the fire, as the IAEA Regulations specify that the thermal test must follow the impact tests. Impact damage included the loss of a certain amount of the intumescent coating as determined from separate tests.
- Determination of the transient temperatures in the package during and after the fire test, up to the point where steady-state conditions were reached once again.

COMPUTER CODE

All the analyses were carried out using the finite element code OASYS LS-DYNA3D (Oasys Ltd 1994). This code is well known for its capabilities in analysing non-linear dynamic stress analysis problems. Recently its capability was increased by incorporating the heat transfer code TOPAZ3D (Shapiro 1985) within DYNA3D. Hence all the mechanical impact, thermal, and thermal stress calculations can be accomplished using one finite element model and one computer code.

All aspects of the code were tested by running simple models and comparing the results with closed-form solutions, and by running more complex models and comparing the results with physical test results, for example tests on 500-litre drums subjected to heating in a furnace. In this way confidence was obtained that realistic results could be obtained from the full models.

The pressure-time history, activity release and effects on the seals were obtained by post-processing the DYNA3D results.

MODEL DESCRIPTION

The models for both the thermal analysis and stress analysis were identical except for a few components. Figures 3 and 4 show the finite element meshes for the RSTC-285 and RSTC-70 half-models. In general, 8-noded solid elements were used. On some components where there was only a single layer of elements (e.g. the parts of the LSM and the transport frame) a layer of shell elements was also used to maintain the correct elastic stiffness.

The bolts in the clamps holding the LSM to the body were modelled using spring elements.

The total number of elements used in each half-model was 57,044 for the RSTC-285 and 44,708 for the RSTC-70.

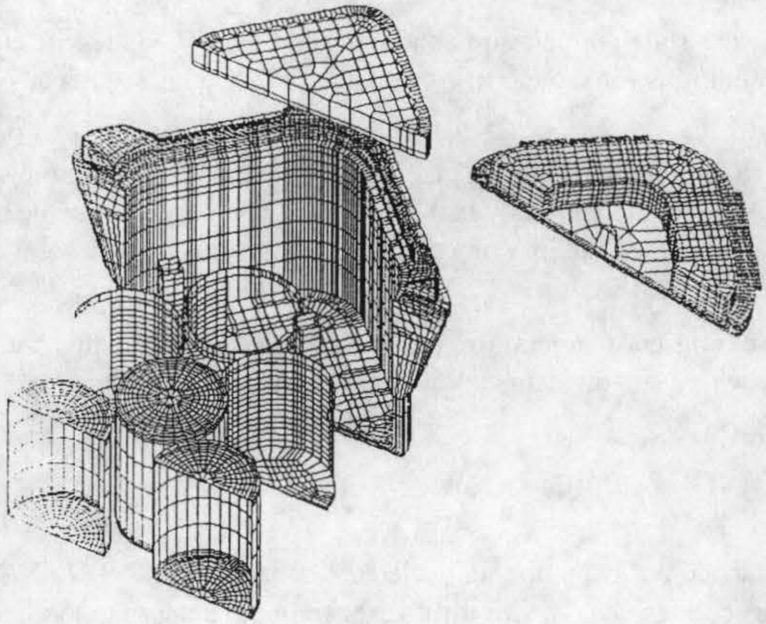

Figure 3. Finite Element Mesh for the 70mm Concept L RSTC

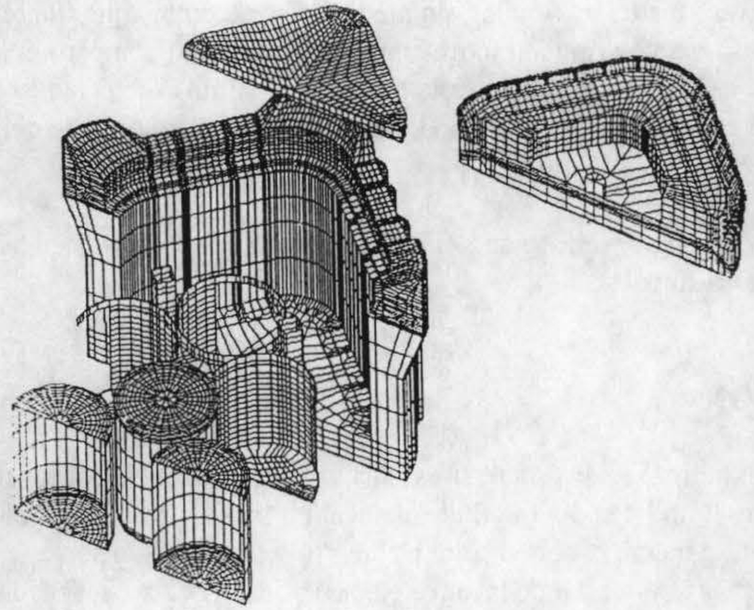

Figure 4. Finite Element Mesh for the 285mm Concept L RSTC

INPUT DATA

The thermal and mechanical properties of the RSTC body and lid (forged steel ASTM A350 Grade LF5) and the stillage, drums, chocks, and cladding (316L stainless steel) were obtained from the ASME Boiler and Pressure Vessel Code.

The thermal properties of the wasteform were based upon those measured by Nirex for cemented Magnox sludge (Bush et al. 1990). Each drum was assumed to generate 50 watts, which is the maximum specified by Nirex. Evaporation of steam from the pore-water in the wasteform was modelled by including a "spike" in the specific heat of the wasteform at 100°C.

BOUNDARY CONDITIONS

During normal conditions the ambient temperature was taken to be +38°C (IAEA 1990). Solar radiation inputs were half the values shown in Table XII of (IAEA 1990), but were taken to apply constantly (i.e. 24 hours a day) rather than 12 hours a day, thus giving the total heat input specified in the regulations.

Free convection and solar radiation were modelled by applying convection elements and heat flux elements to the intumescent coating.

During the fire the flame emissivity and surface absorptivity were each taken to be 1.0 for conservatism.

RESULTS - NORMAL CONDITIONS OF TRANSPORT

This involved the calculation of the temperature distribution within each of the two RSTCs under the steady-state normal conditions of transport. The maximum predicted temperature in the waste is 66°C in the case of the RSTC-285 and 65°C in the case of the RSTC-70. In both cases the highest temperature is towards the top of the drum, because of the greater solar radiation on the top of the RSTC.

The waste temperatures are acceptable: the maximum is well below 100°C, the temperature at which steam would begin to be driven off the cement matrix which immobilises the waste.

RESULTS - FIRE TEST CONDITIONS

The model for the fire test analysis used as its initial conditions the steady-state temperature distribution calculated for normal conditions, together with the deformed geometry obtained from an analysis of a 9-metre drop onto an unyielding target in the lid corner attitude. The transport frame and drums were positioned as close as possible to the damaged corner so as to maximise the heat input to the waste.

The peak temperatures for the waste in the RSTC-285 and RSTC-70 occurred at 5½ hours after the start of the fire. Table 1 summarizes the principal results of the analysis.

The activity release from the waste into the cavity was calculated using experimentally measured release fractions for Magnox sludge (Bush et al 1990). Radionuclide-specific release fractions measured on active waste samples at 300°C were applied to any portion of the waste whose temperature exceeded 100°C, for conservatism. The maximum total activity released from the waste into the RSTC cavity was calculated to be $0.0024A_2$ (Table 1), which is much smaller than the allowable release from the cavity to the outside (IAEA 1990) under accident conditions.

Using the RSTC-70 LSM seal temperature-time history it was calculated that the entire transient was equivalent to 1 hour at a constant temperature of 200°C. In the tests carried out by Nirex on the candidate seal material (McKirdy et al. 1994) the seal materials were subjected to 5 hours at 200°C, with satisfactory performance. Hence the seals will still be effective in providing containment to the RSTCs after the fire test.

	RSTC-285	RSTC-70
Max waste temperature (°C)	120	107
Waste volume at a temperature greater than 100°C (litres)	27.5	23
Maximum seal face temperature (°C)	123	182
Total activity released into RSTC cavity (A_2)	0.0024	0.0021

Table 1 Summary of Predicted Results

CONCLUSION

The analysis showed that the current designs of RSTC-285 and RSTC-70 are capable of satisfying the IAEA fire test requirements (IAEA 1990) following an impact from 9m on to an unyielding target.

REFERENCES

Bush, R P et al. *Fire Testing of Fully Active Medium Level Wasteforms.* Report No EUR 14100 EN, Commission of the European Communities, 1993.

International Atomic Energy Agency. *Regulations for the Safe Transport of Radioactive Material.* 1985 Edition (as amended 1990), Safety Series 6, 1990.

McKirdy, B J et al. *Testing of the Sealing Arrangements for the Nirex Reusable Shielded Transport Containers.* International Journal of Radioactive Materials Transport, Vol 5, No 2-4, PP 189 - 192, 1994.

Oasys Ltd, *OASYS-LS-DYNA3D, Version 6.0.* Oasys Ltd, 13 Fitzroy Street, London, W1P 6BQ, 1994.

Shapiro, A B. *TOPAZ-3D, A 3-Dimensional Finite Element Heat Transfer Code.* Lawrence Livermore National Laboratory, August 1985.

Sievwright, R W T et al. *Development of Sealed Type B Transport Containers for the Transport of Intermediate Level Radioactive Waste.* International Journal of Radioactive Materials Transport, Vol 2, Nos 1-3, PP 169-177, 1991.