DESIGN, SAFETY ANALYSES AND TESTS OF PACKAGINGS FOR HLW AND SPENT FUEL TRANSPORT/STORAGE

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Abstract

DESIGN, SAFETY ANALYSES AND TESTS OF PACKAGINGS FOR HLW AND SPENT FUEL TRANSPORT/STORAGE.

On the basis of the provisional specifications of residues generated by a reprocessing plant, a conceptual design was prepared of a large packaging (with a total weight of 95 to 124 t) for high level vitrified solid wastes. Unlike spent fuel, the contents (vitrified solid wastes) are to be stored and disposed of after transportation. It is therefore necessary to pay extra attention to vibration and impact during transportation. Accordingly, the interactions between the packaging and the contents, and between one set of contents and another were clarified. A composite drop analysis was also carried out, as a result of which a method for analysing impacts on the contents during transportation was established. As a part of integrity assessment tests using model packages, drop tests and thermal tests were carried out on the model packages. The composite behaviour of the contents and their integrity were successfully verified. It was assumed that casks similar to the transport storage casks developed and licensed in Europe and in the United States of America could be used in Japan in the future. However, the conceptual designs of these transport/storage casks were modified to meet specifications applicable in Japan. Safety (in particular shielding) and economic considerations influenced the conceptual designs that were evolved of structurally simple cask-storage buildings, while taking account of the strength of the cask. Seismic safety analysis is important in Japan. Since the casks already meet transport standards (for example, they pass the 9 m drop test) and have sufficient structural strength, the integrity of the casks was shown to be maintained even in the event of a total collapse of the storage building.

1. PACKAGINGS FOR HLW TRANSPORT

1.1. Objective

Wastes from the reprocessing of spent fuel, commissioned at British Nuclear Fuels Limited (United Kingdom) and Cogéma (France), are returned to Japan.

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This study seeks to analyse the safety aspects of international transportation of these returnable HLW to Japan, and hopes to contribute to the preparation of technical documents for applying for approval of the specifications by the Government of Japan. The results of studies on high level vitrified solid waste packages (which are one of the forms of returnable reprocessing waste packages) are presented.

1.2. Method

The overall approach of the study is shown in Fig. 1. As shown in the figure, the study consisted of two streams, both leading to the final results. One stream focused on the analytical examination of actual packages (items (1)–(5)), while the other stream was experimental examination, using partial model casks (items (1) and (2) and (6)–(10)). Both streams, however, were integrated with each other in the final stage (items (11) and (12)) and the results were used in the overall assessment of high level returnable waste packages.

1.3. Results

1.3.1. Design of a large packaging (item (1) of Fig. 1)

On the basis of the provisional specifications of the residues provided by Cogéma, a conceptual design was developed of a large packaging (with a total weight of 95–124 t) for high level vitrified solid wastes (Fig. 2).

1.3.2. Detailed analyses (item (3) of Fig. 1)

Three-dimensional analysis was carried out after the packaging was dropped on its end, as was thermal analysis, which considered the natural convection around the packaging. These analyses were carried out to supplement previous analyses of spent fuel transport cask designs. The results of the package drop are shown in Fig. 3. In addition, a detailed analysis comparing existing data with the analytical method was carried out to improve the accuracy of the analysis.

1.3.3. Package integrity assessment tests (item (9) of Fig. 1)

As part of the series of integrity assessment tests, drop and sealing and heat-transfer and fire-resistance tests were carried out on the model packages. The composite behaviour of the contents, and their integrity, were successfully verified. The results of the drop test are shown in Table I.

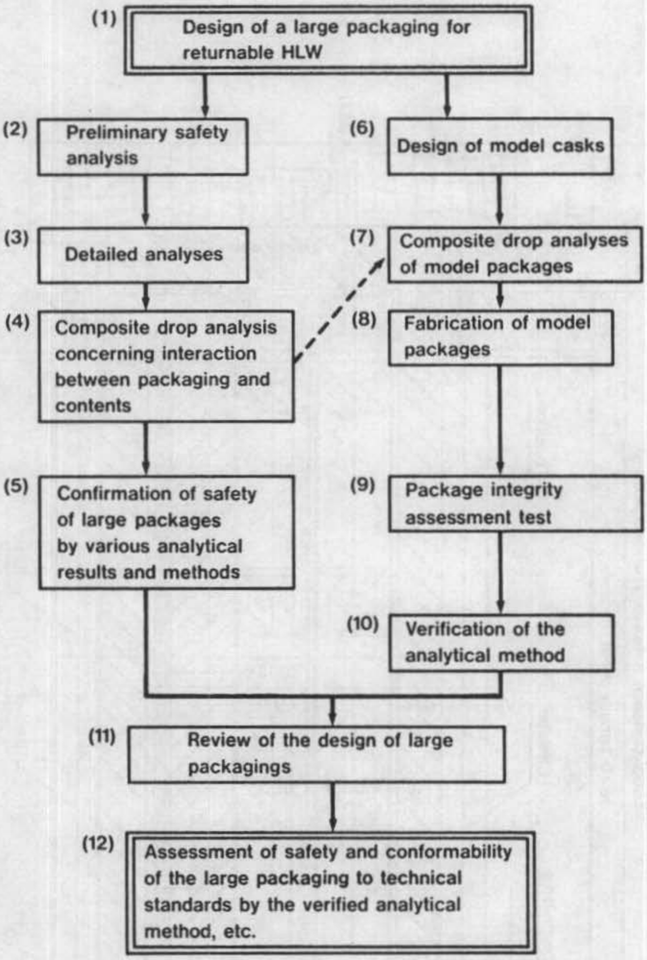


FIG. 1. Chart showing the overall approach of the study.

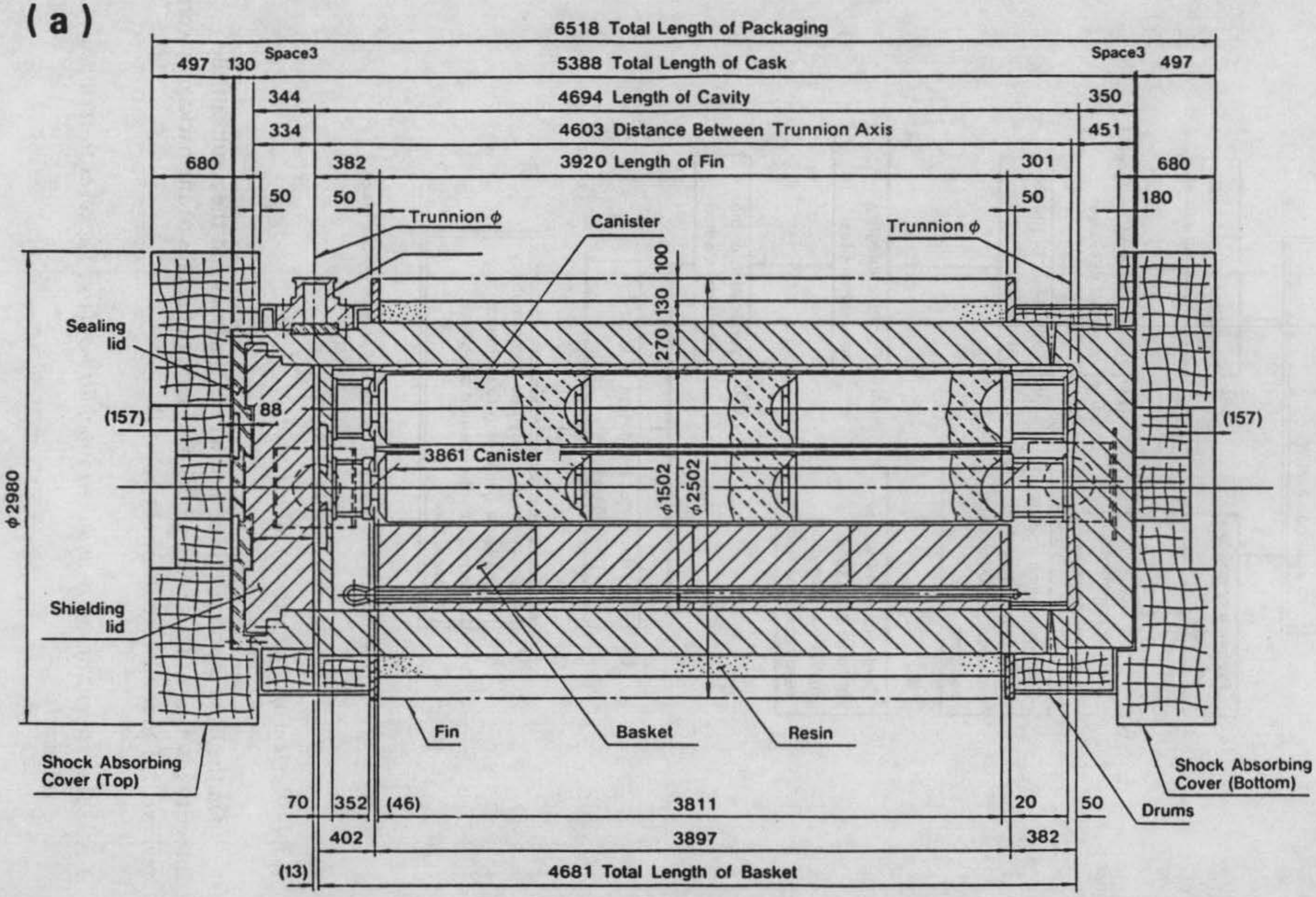
1.3.4. Review of the design of large packages

On the basis of the results of a variety of analyses and the results of the integrity assessment tests using model packages, the details of the packaging were reviewed. The results are shown in Table II.

1.3.5. Assessment of safety and conformability of large packages to technical standards

The large packages examined above were subjected to a safety analysis using the verified analytical method. Further, the packages were assessed for their degree

(a)


6518 Total Length of Packaging
497
130
Space3
5388 Total Length of Cask
Space3
497
344
4694 Length of Cavity
350
334
4603 Distance Between Trunnion Axis
451
680
382
3920 Length of Fin
301
680
50
50
Trunnion ϕ
Canister
Trunnion ϕ
50
180
100
130
270
Sealing lid
88
(157)
(157)
3861 Canister
ϕ1502
ϕ2502
ϕ2980
Shielding lid
Fin
Basket
Resin
Shock Absorbing Cover (Top)
Shock Absorbing Cover (Bottom)
Drums
70
352
(46)
3811
20
50
402
3897
382
(13)
4681 Total Length of Basket

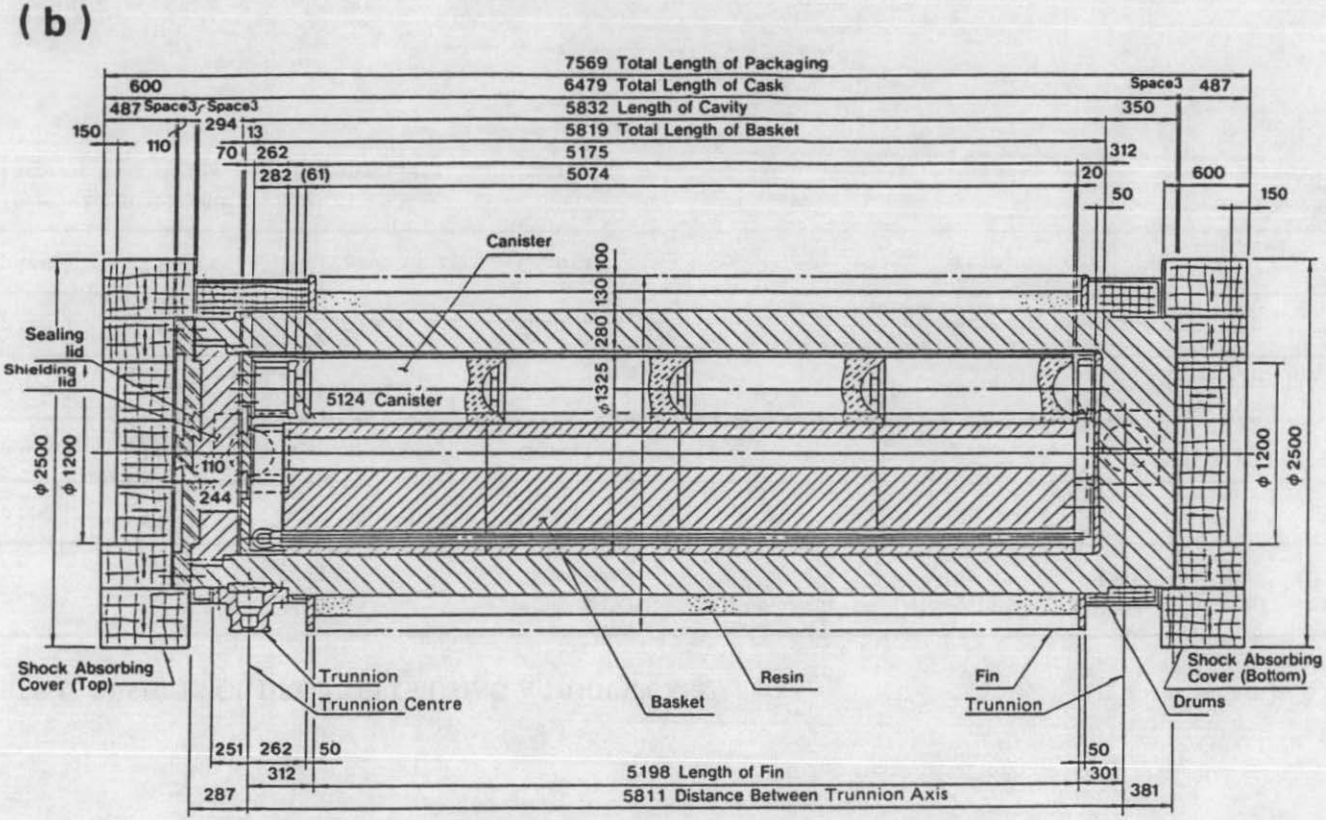


FIG. 2. *Details of a large packaging. (a) Type A2, (b) Type B2.*

TABLE I. RESULTS OF DROP TESTS USING A MODEL CASK

Item	Model	Material of spacer	Filled material of canister	Drop height (m)	Deformation of spacer	Bottom canister	Medium canister	Top canister
Drop test 1	3 Stages	Aluminium alloy	Cement	0.3	No	○	○	○
Drop test 2	2 Stages	Aluminium alloy	Cement	9	Yes	○	–	○
Drop test 3	3 Stages	Carbon steel	Cement	9	No	X	○	○
Drop test 4	2 Stages	Carbon steel	Glass	9	No	X	–	○
Drop test 5	3 Stages	Aluminium alloy	Cement	9	Yes	○	○	○

○: There is no trouble with discharge.
X: There are some troubles with discharge.

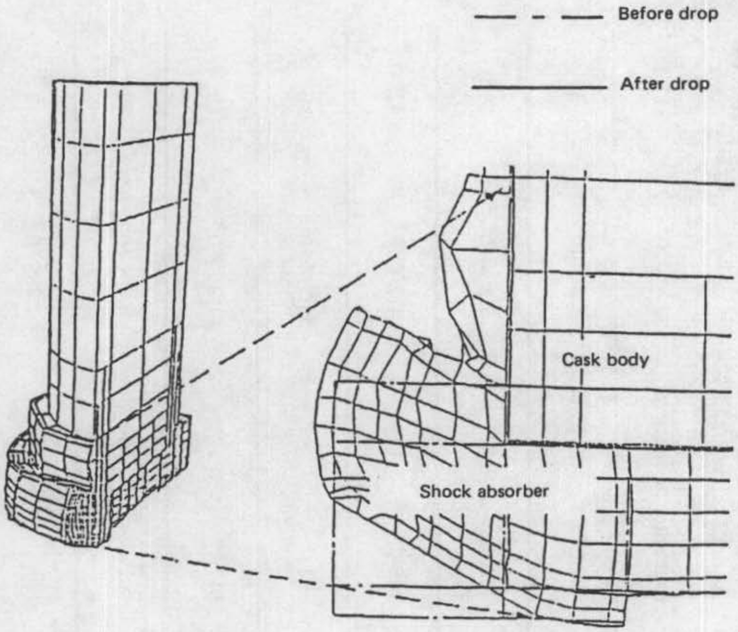


FIG. 3. Results of a test involving the cask being dropped on its edge (final configuration).

of conformity with the 1985 IAEA Transport Regulations and with the domestic laws and regulations in force. The large packaging discussed in this study was found to be safe for international and domestic transportation of returnable HLW, and fully maintained the integrity of the contents.

2. PACKAGINGS FOR SPENT FUEL TRANSPORT/STORAGE

2.1. Conceptual design of a transport/storage cask and storage building

The objective of this study was to examine the safety of a cask storage system of simple design. It was assumed that the transport/storage casks which had been developed and licensed in Europe and in the United States of America could be used in Japan in the future.

During transport, casks have certain shielding capabilities that are based on transport rules. During storage, however, many casks are stored in a centralized manner and the cask storage building itself may require a considerable shielding capability under some siting conditions. In this study, safety (in particular, shielding) and economic considerations influenced the conceptual designs of a

TABLE II. COMPARISON OF DETAIL DESIGNS FOR HIGH LEVEL WASTE PACKAGINGS

Category			Material and name of packaging	Maximum dimension (m)		Weight (t)		Radioactivity	Heat generation
				Outer diameter	Length	Packaging	Package	(Ci)[a]	(kW)
High level reprocessing wastes	Contents	Glass solid	Stainless steel canister	0.4	1.3	0.075	0.48	5.8×10^5	2
	Packaging	Type A1 (14 canisters)	Forged cask	2.9	5.3	88	95	7.3×10^6 [b]	28[b]
		Type A2 (21 canisters)	Forged cask	3.0	6.5	109	119	1.2×10^7	42
		Type B1 (15 canisters)	Forged cask	2.5	6.2	92	99	8.7×10^6	30
		Type B2 (20 canisters)	Forged cask	2.5	7.6	111	121	1.2×10^7	40
		Type C1 (15 canisters)	Cast-iron cask	2.7	5.6	102	109	8.7×10^6	30
		Type C2 (20 canisters)	Cast-iron cask	2.7	6.9	115	124	1.2×10^7	40

[a] 1 Ci = 3.70×10^{10} Bq.
[b] Cooled ten years after discharge. Others were cooled for 6.5 years.

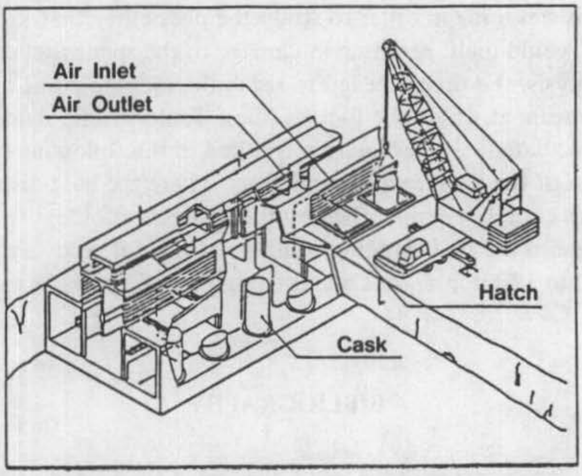


FIG. 4. Conceptual view of a trench-type cask storage building.

trench system using truck cranes (see Fig. 4) and an individual shielding-type storage building for at the reactor (AR) storage. For away from the reactor storage, a conceptual design of a simple concrete building was evolved.

2.2. Analyses of earthquake damage

A series of safety analyses were carried out on the above-mentioned cask and cask storage buildings. Evaluating the effects of an earthquake on safety is of great interest and is described below.

2.2.1. Structural integrity of the cask

Such eventualities as the falling of the roof, walls, concrete beams, steel beams and crane, caused by destruction of the cask storage building were considered. The analysis also evaluated the allowable acceleration of the cask (120g), comparing it with the acceleration of the cask when calculated statically, by measuring the absorption energy caused by plastic deformation of reinforced concrete and structural steel. It was concluded that nothing that fell on the cask affected its integrity as long as the cask itself satisfied the design criteria for a transportation cask.

2.2.2. Cooling performance of the cask

If the cask were to be buried by the rubble of a destroyed building, it is clear that its cooling performance would decline. Therefore, non-steady-state thermal analysis was done in order to study the possibility that the gamma shield material (lead) would melt, resulting in damage to the spent fuel cladding.

In the analysis, the times needed to reach the melting point of lead (327°C) and the temperature at which the fuel cladding would sustain damage (about 560°C) were calculated. The evaluation resulted in the following conclusions. Even in the case of the most severe conditions, where the heat dispersion from the cask surface was completely disturbed by the concrete rubble, the lead would not melt and damage to the fuel cladding could be avoided if recovery countermeasures were taken within 120 hours, thus maintaining the safety of the cask.

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