Long-term Sealability of Spent Fuel Casks

O.Kato[1], A.Kosaki[1], C.Ito[1], S.Ozaki[1], S.Iitsuka[2]

[1] Central Research Institute of Electric Power Industry, Tokyo;

[2] Central Research Service Co., Tokyo, Japan

INTRODUCTION

In Japan, fuel reprocessing is recognized as one of the policies of the nuclear fuel cycle. But, in the future, the discharge of spent fuel is expected to exceed the fuel reprocessing capacity.

Thus, it is necessary to establish methods for intermediate storage of spent fuel before its reprocessing to give flexibility to the nuclear fuel cycle. The spent-fuel cask-storage method is rational and economical. It requires, however, the function of sealing radioactive materials in casks, and the storage duration may sometimes continue for 40 or 50 years, so casks must have long-term sealability.

For this purpose, a survey and tests on the long-term sealability of spent fuel casks were started in our institute at 1985 to evaluate the sealability, and we have been striving to accumulate and expand our basic data since that time.

This report presents the results of long-term sealability test of full-scale model casks which have been in progress since 1990. (O.Kato and C.Ito 1992)

The purpose is to confirm the long-term sealability of the casks.

SEALING STRUCTURE OF CASKS

There are two methods to seal casks; the first is to weld the body and the lid together, and the second is to use gaskets. The former method is reliable, but it is difficult to remove the contents at the end of storage, so the latter method has been generally adopted.

The typical sealing structure of the lid part of a cask for transport and storage of spent fuel which is at the stage of development or confirmation is shown in Fig. 1.

In this cask, multi-obstruction structure consisting of primary and secondary lids and a protection cover is adopted. The containment function is secured by inserting gaskets between the cask body and the lid and then bolting them together. Metal gaskets are adopted for long-term durability.

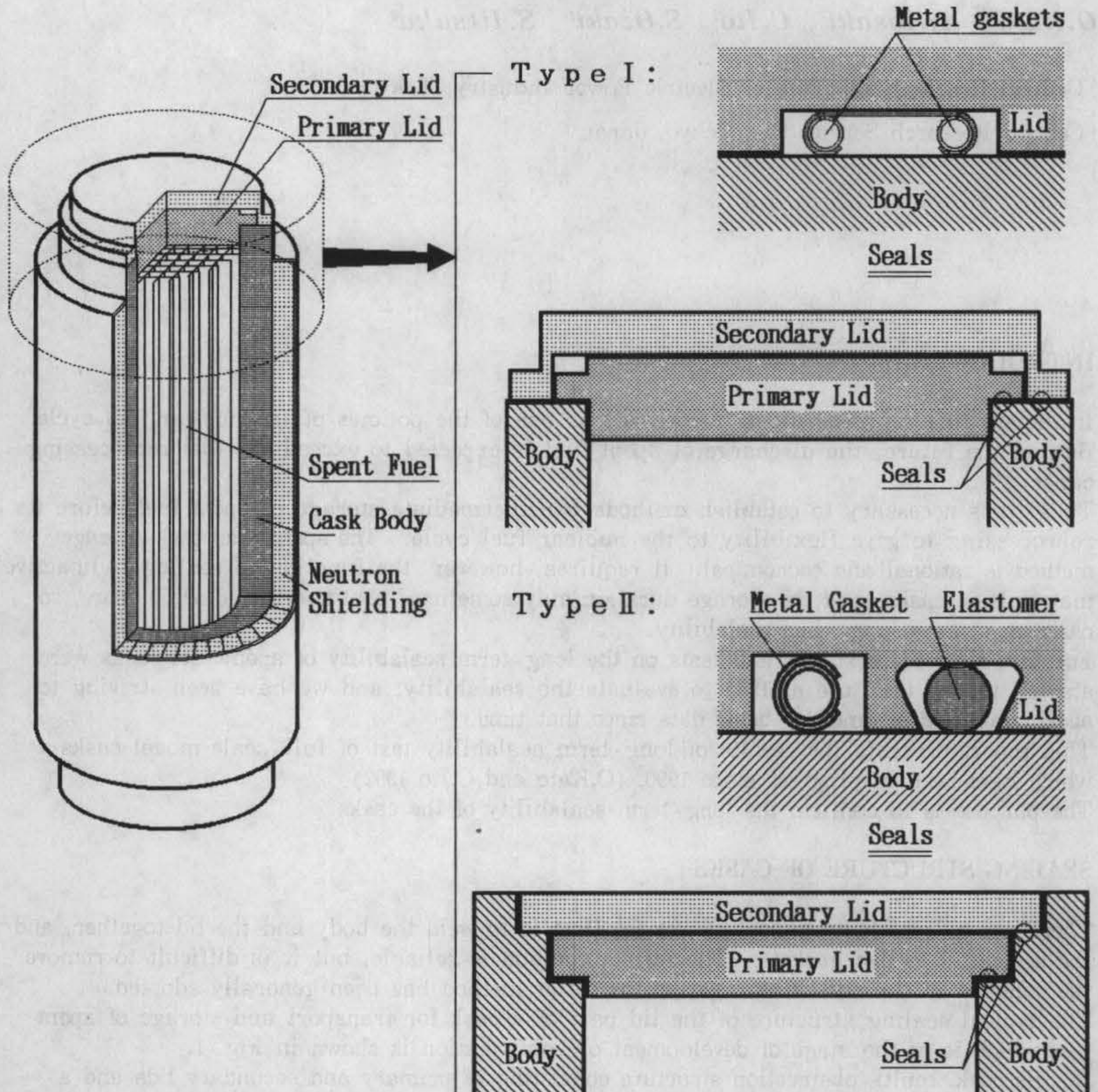

Figure 1 General View of Spent Fuel Storage Cask and Seal Structure

LONG-TERM SEALABILITY TEST

Test models

Fig. 2 shows the two kinds of tested lids, parts of full-scale cask models selected from the casks being developed and confirmed.
They are selected because of their lid shapes, seal grooves, and the sealing structure of their gaskets, which have direct influence on sealability.
The principal specifications of these test models are shown in Table 1.

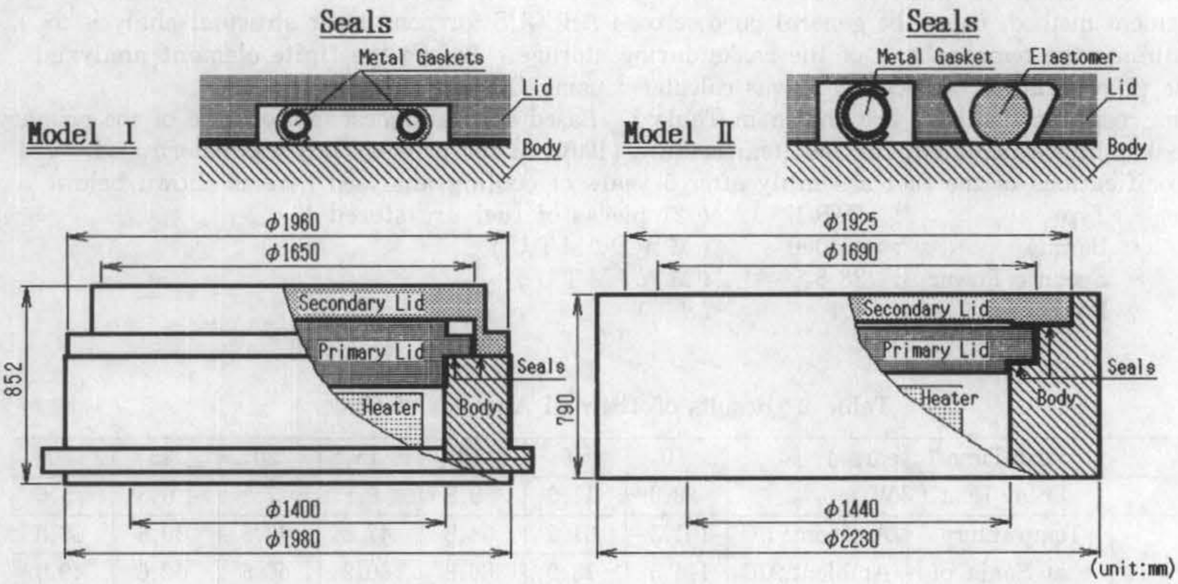

Figure 2 Details of Test Models

Table 1 Principal Specifications of Test Models

Items			I - type model	II - type model
Body		Material	Forged Carbon Steel	Ductile Cast Iron
		Size	Outer dia. : 1980 mm	Outer dia. : 2230 mm
		Finish	Stainless steel padding	Nickel plating
Primary Lid		Material	Forged Carbon Steel	Stainless Steel
		Size	Outer dia. : 1654 mm	Outer dia. : 1690 mm
		Finish	Stainless steel padding	Stainless Steel
Secondary Lid		Material	Forged Carbon Steel	Stainless Steel
		Size	Outer dia. : 1960 mm	Outer dia. : 1925 mm
		Finish	Stainless steel padding	Stainless Steel
Gaskets	Inside	Material	Aluminum / Inconel	Silver / Inconel
		Size	Thickness : 6.1 mm	Thickness : 10 mm
	Outside	Material	Aluminum / Inconel	Silicone rubber
		Size	Thickness : 6.1 mm	Thickness : 10 mm

In the I-type model, the barrel part and lid are made of forged carbon steel. The sealing surface is padded with stainless steel (SUS 304), and a double metal gasket is used.
In the II-type model, the barrel is made of spheroidal graphite cast iron, and the lid is made of stainless steel. The sealing surface of the barrel is nickel plated. In this model, an inner metal gasket (silver envelope), and an outer rubber gasket (silicon rubber) were used.
In both models, the heat from the decay of spent fuel is simulated by heaters installed in the cavities.

Test conditions

The heat condition analysis was performed on about three kinds of cask models by the finite element method, using the general purpose code ABUQUS for non-linear structual analysis to estimate the temperatures of the casks during storage. Before the finite element analysis, the time variation of decay heat was calculated using ORIGEN 2 code.
The results of analysis are shown in Table 2. Based on the highest temperature of the primary gasket thus calculated, the test temperature (160℃ at the primary lid) was determined. The specifications of the fuel assembly after 5 years of cooling analysed here is shown below.

- Type : PWR 17× 17 (21 pieces of fuel are stored)
- Burnup : 43,000 (MWD / MTU)
- Specific Power : 38.3 (MW / MTU)
- Enrichment : 4.1 (%)

Table 2 Results of Thermal Analysis of Casks

		Past Time (years)	0	5	10	15	20	25	30
		Decay Heat (kW)	23.0	11.5	9.8	8.1	7.2	6.3	5.6
Cask A	Temperature at Seals of Primary Lid	Ambient: 5℃	101.3	61.5	54.8	47.8	43.8	39.8	36.5
		Ambient:20℃	111.5	73.2	66.8	60.2	56.5	52.6	49.5
		Ambient:40℃	125.5	89.3	83.3	77.1	73.6	69.8	67.1
	Temperature at Seals of Secondary Lid	Ambient: 5℃	101.2	61.4	54.8	47.8	43.8	39.8	36.5
		Ambient:20℃	111.4	73.2	66.8	60.2	56.4	52.6	49.5
		Ambient:40℃	125.4	89.3	83.3	77.1	73.6	69.8	67.1
Cask B	Temperature at Seals of Primary Lid	Ambient: 5℃	65.3	40.2	36.1	31.8	29.4	26.9	24.8
		Ambient:20℃	78.5	54.1	50.1	45.9	43.5	41.1	39.2
		Ambient:40℃	96.0	72.5	68.8	64.7	62.4	59.3	58.3
	Temperature at Seals of Secondary Lid	Ambient: 5℃	62.5	38.8	34.9	30.8	28.4	26.1	24.1
		Ambient:20℃	75.5	52.6	48.8	44.8	42.6	40.3	38.4
		Ambient:40℃	92.9	71.0	67.4	63.6	61.4	58.5	57.5
Cask C	Temperature at Seals of Primary Lid	Ambient: 5℃	131.7	76.6	67.6	58.4	53.2	47.9	43.7
		Ambient:20℃	141.8	88.3	79.7	70.8	65.9	60.8	56.8
		Ambient:40℃	156.0	104.6	96.4	87.8	83.1	78.3	74.5
	Temperature at Seals of Secondary Lid	Ambient: 5℃	127.3	74.2	65.6	56.7	51.7	46.6	42.4
		Ambient:20℃	137.4	86.0	77.7	69.1	64.4	59.4	55.6
		Ambient:40℃	151.7	102.3	94.4	86.2	81.7	77.0	73.3

Testing method

The outline of the test is shown in Fig. 3. The primary lid with a gasket and barrel was bolted together. The model cavity was filled with helium gas in order to keep 0.8 atm. at thermal equilibrium. Then the sealability of the primary lid was tested by a helium leakage test.
Next, the secondary lid was installed. The space between the primary and secondary lids was filled with helium gas to 4 atm. in I-type model, and to 6 atm. in II-type model, and then sealability was tested.
As mentioned above, the sealability of the models was confirmed before tests, the prescribed test temperatures were kept by heating models using the heaters installed in the cavities, the pressures between the primary and secondary lid were measured, and the sealability of the primary lid was watched. The secondary lid was tested by a helium leak detector about every week.

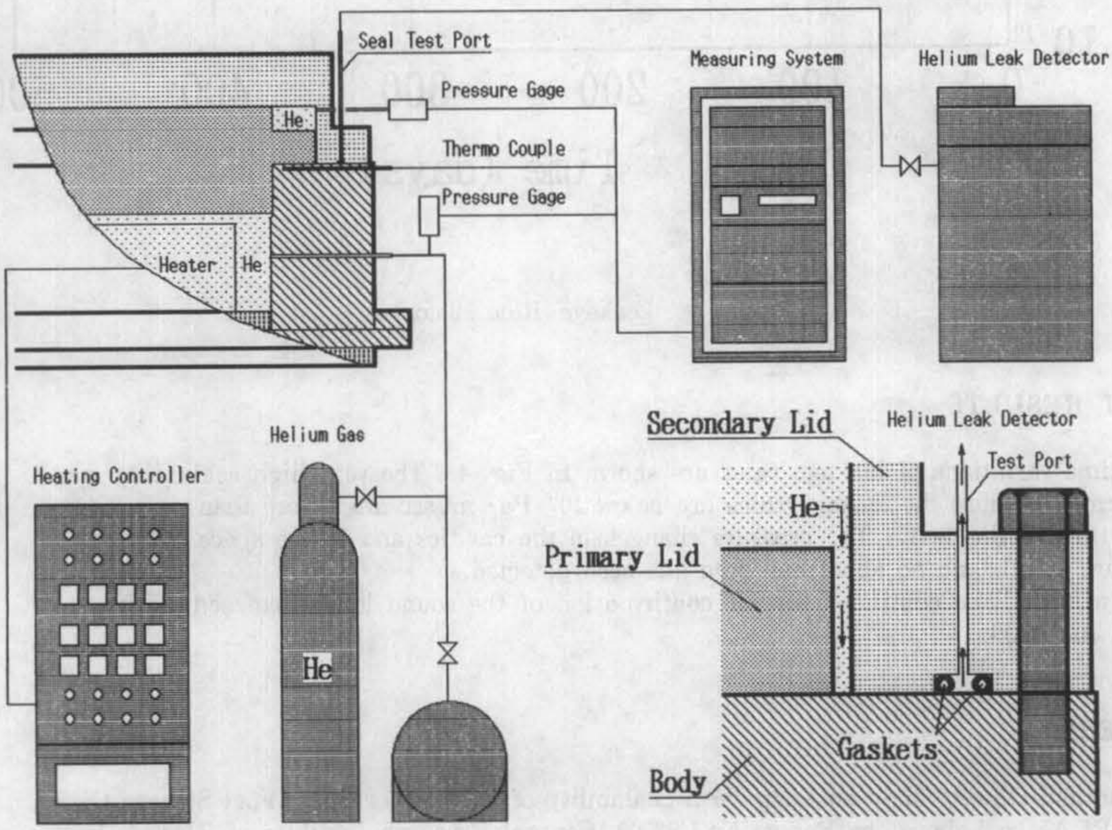

Figure 3 Outline of the Long-term Sealability Test

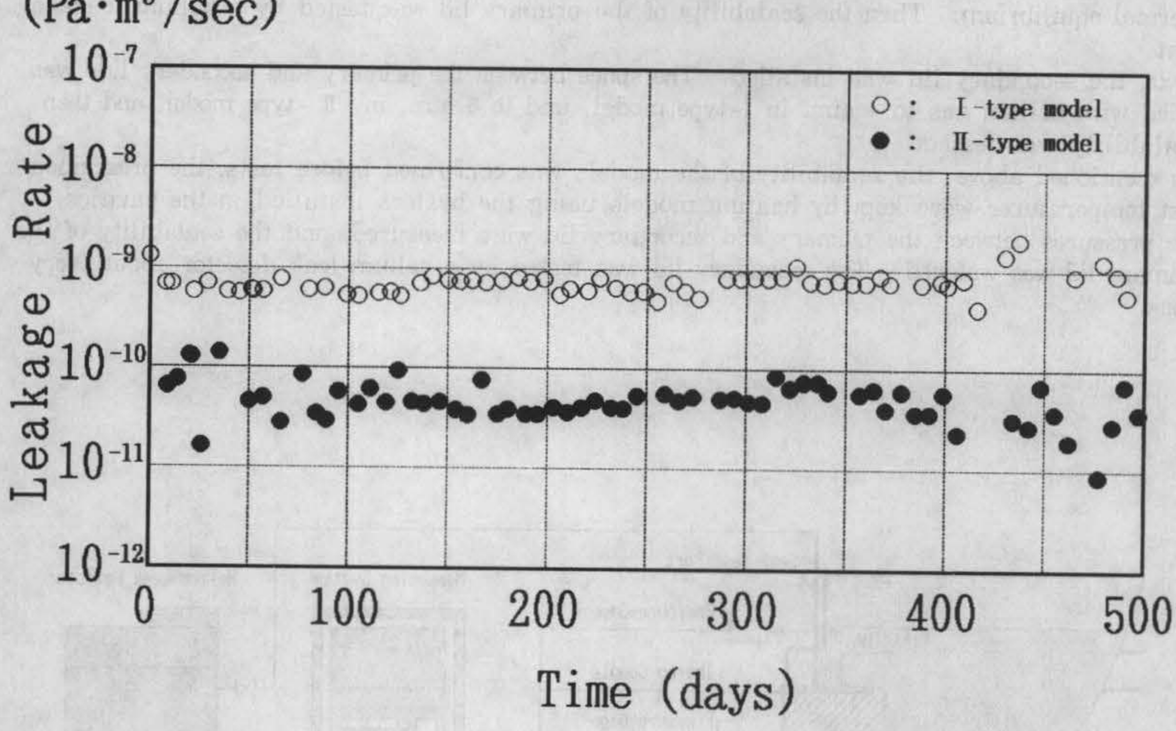

Figure 4 Leakage-Rate Histories

TEST RESULTS

The time variations of leakage rates are shown in Fig. 4. The very high sealability was confirmed because the leakage rates are below 10^{-9} Pa · m³/sec after more than a year from the start of the test. The pressure changes in the cavities and in the space between the lids are small, and no abnormal state has been detected.
This test shall be continued for the confirmation of the sound long-term sealability of spent fuel casks.

REFERENCE

O.Kato and C.Ito, "Study on Long-term Sealability of Gaskets for Spent Fuel Storage Cask", CRIEPI Abiko Laboratory Report No.U92009, Central Research Institute of Electric Power Industry (1992).