Experience of Fabrication of Transport/Storage Packaging "TN24"

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INTRODUCTION

It is the basic plan of Japan that nuclear spent fuel would be reprocessed. More recently, however, recognition has gradually been taken of the necessity for an interim storage to support the reprocessing of the spent fuel. This trend of having an interim storage is common in many other countries, and various storage methods have been developed, using the package, pool, vault, silo, and others.

Taking this experience into account, Kobe Steel Ltd. has been engaged since 1983 in a joint project with the French company, Transnucleaire, to develop "TN24", a dry-type storage packaging for nuclear spent fuel. The combination of Transnucleaire's design experience from developing the TN12/TN17 transport packaging, together with Kobe Steel's technologies and expertise in manufacturing and quality assurance, have made TN24 a high-efficiency storage package.

In 1985, drop tests, using a 2/5-scale model of a TN24, demonstrated the soundness of the packaging under accident conditions. In 1986, a prototype model was manufactured and various cold tests were carried out in Japan. This prototype model was sent to the Idaho National Engineering Laboratory in the United States for storage tests using actual irradiated fuel assemblies.

Recently Kobe Steel fabricated a Japanese version of the TN24 packaging, which has been adopted for actual use in the Tokyo Electric Power Company's Fukushima No. 1 site.
This report describes the stages in the development of the TN24 packaging, from design to the present.

DESIGN CONCEPT OF THE TN24 PACKAGING

The Japanese version of the TN24 packaging has got the storage license in 1994. But it has not only the functions of interim storage but also the functions of transport. It satisfies

the requirements for storage, the Japanese Nuclear Safety Commission's report, "Dry Cask Storage of Spent Fuel in Nuclear Power Plants." And it also satisfies the IAEA transportation regulations requiring a B(U) type of package.

The Japanese version TN24 storage packaging has the following features:

- The shell lid and bottom plate have an extremely robust structure since their main structural material is forged carbon steel. The materials have been forged by a 13,000-ton press machine of Kobe Steel
- The main body is a combination of a shell and a bottom with a circumference weld.
- The inner surface of the body is coated with a metal spray, and the outer surface is painted in addition to a metal spray coating.
- A metallic double gasket is used for the containment system to keep it satisfactorily leak-proof for a long period of time.
- The "egg-crate" structure basket, which is made of a borated aluminum alloy, has a high storage efficiency and an excellent subcriticality capability.
- For the shielding material, a silicone rubber-based neutron shielding material developed by Kobe Steel is used. This material ensures both a high shielding capability and long-term heat resistance at high temperatures.

SPECIFICATIONS OF THE PACKAGING

The specification of the Japanese version TN24 packaging, which is designed in accordance with the design requirements for interim storage, is shown in Table 1 and Figure 1.

The following design considerations were taken into account for this design.

Heat Removing Structure

- The spent fuels are loaded in a compartmentalized structure of the basket in the cavity.
- An aluminum alloy which have good thermal conductivity is used for the basket.
- The cavity of the packaging is filled with helium gas, which has a higher thermal conductivity.
- Copper plates are provided to improve the heat conduction in the neutron shielding layer, which has a relatively low thermal conductivity.

Containment Structure

- Metal double gaskets with high durability against heat and corrosion are used for the seals of the lids and that of penetration holes in lids.
- There are two containment boundaries: one is consisting of the main body, the primary lid, the penetration hole of the primary lid, and their seals; and the second, the monitoring boundary, consisting of the main body, the primary lid, the secondary lid, the penetration holes of the two lids, and their seals.
- The pressure barrier is created through maintaining negative pressure inside the packaging and positive pressure between the lids.
- The integrity of the containment function can be monitored by checking the pressure between the two lids with a pressure sensor. If leakage occurs at either of the double

containment seals, the pressure decrease between the double lids will be detected. Even in this case, negative pressure is maintained inside the packaging so that the gas inside the packaging is not released directory into the air.

Shielding Structure

- The gamma radiation shielding is mainly constructed of the same forged carbon steel as the main body, lid, and bottom plate.
- The neutron shield is the Kobesh, a silicone rubber-based neutron shielding material developed by Kobe Steel which ensures both a high shielding capability and long-term heat resistance.
- The neutron shielding is installed in the bottom plate and the secondary lid because the packaging is to be stored in a horizontal position.

Subcriticality Structure

- The lattice construction of the basket supports the spent fuel in an appropriate geometric configuration.
- The borated aluminum alloy, which effectively absorbs neutrons, is used for the basket.

Table 1. Specifications of the Japanese-version TN24

	BWR	PWR
CONTENTS		
Fuel Type	BWR	PWR
Fuel Assemblies	52	24
Thermal Power	app. 30kW	app. 30kW
Enrichment (Initial)	3.0%	3.7%
Burn-up	33,000MWD/MTU	35,000MWD/MTU
Cooling Period	4year	5year
DIMENSIONS (mm)		
Cavity Diameter	app. 1,500	app. 1,500
Cavity Length	app. 4,500	app. 4,200
Fuel Compartment Sections	app. 150×150	app. 220×220
External Diameter	app. 2,400	app. 2,400
Length During Storage	app. 5,600	app. 5,300
MATERIAL		
Shell	Forged Carbon Steel	Forged Carbon Steel
Primary Lid	Forged Carbon Steel	Forged Carbon Steel
Basket	Borated Aluminum Plate	Borated Aluminum Plate
Neutron Shield	Kobesh SR-T	Kobesh SR-T
MASSES(kg)		
Total During Storage	app.115,000	app.116,000

DEMONSTRATION TEST

The prototype model and the 2/ 5-scale model were designed and fabricated to perform the demonstration test. The prototype was submitted to performance tests in heat removing and containment. A summary of the tests administered is given in Table 2. Subsequently, this prototype model was delivered to the Virginia Power Company for an additional performance test using spent fuel.

The 2/5-scale model shown in Photo 1 underwent the drop test, as shown in Photo 2, and technical data useful for safety analysis were obtained. The drop test was of course performed according to IAEA regulations.

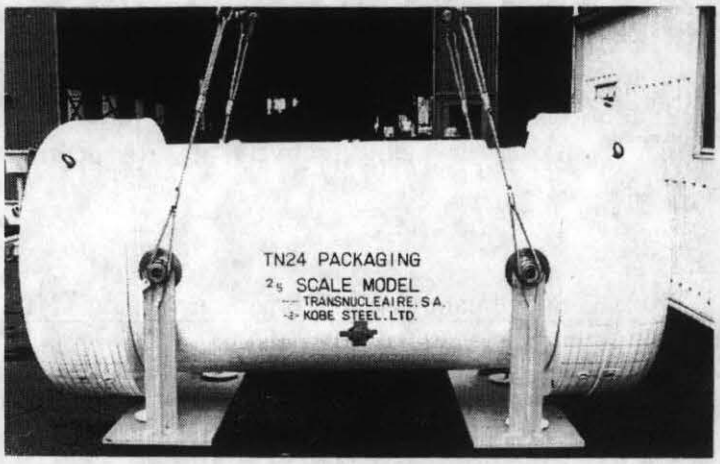

Photo 1. 2/5–scale model of TN24 packaging

Table 2. Summary of Performance Test

Item	Summary
Thermal Test	Position: horizontal, vertical Cavity gas: He, N_2 Thermal Power: <30kW
Containment Test	Leak Tightness

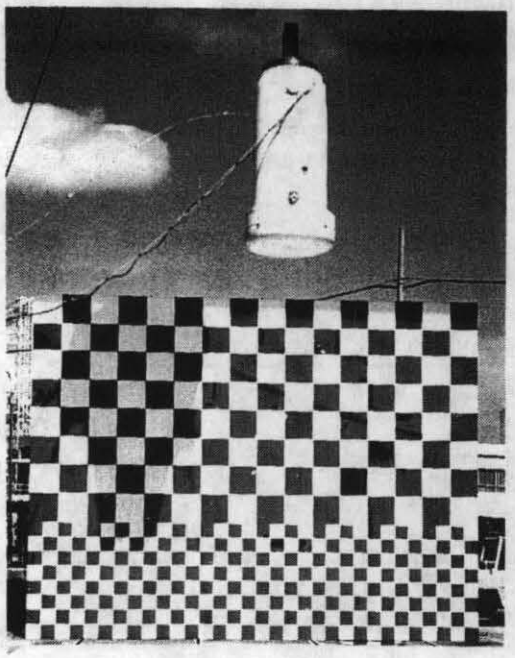

Photo 2. 9m vertical drop test conducted on scale model

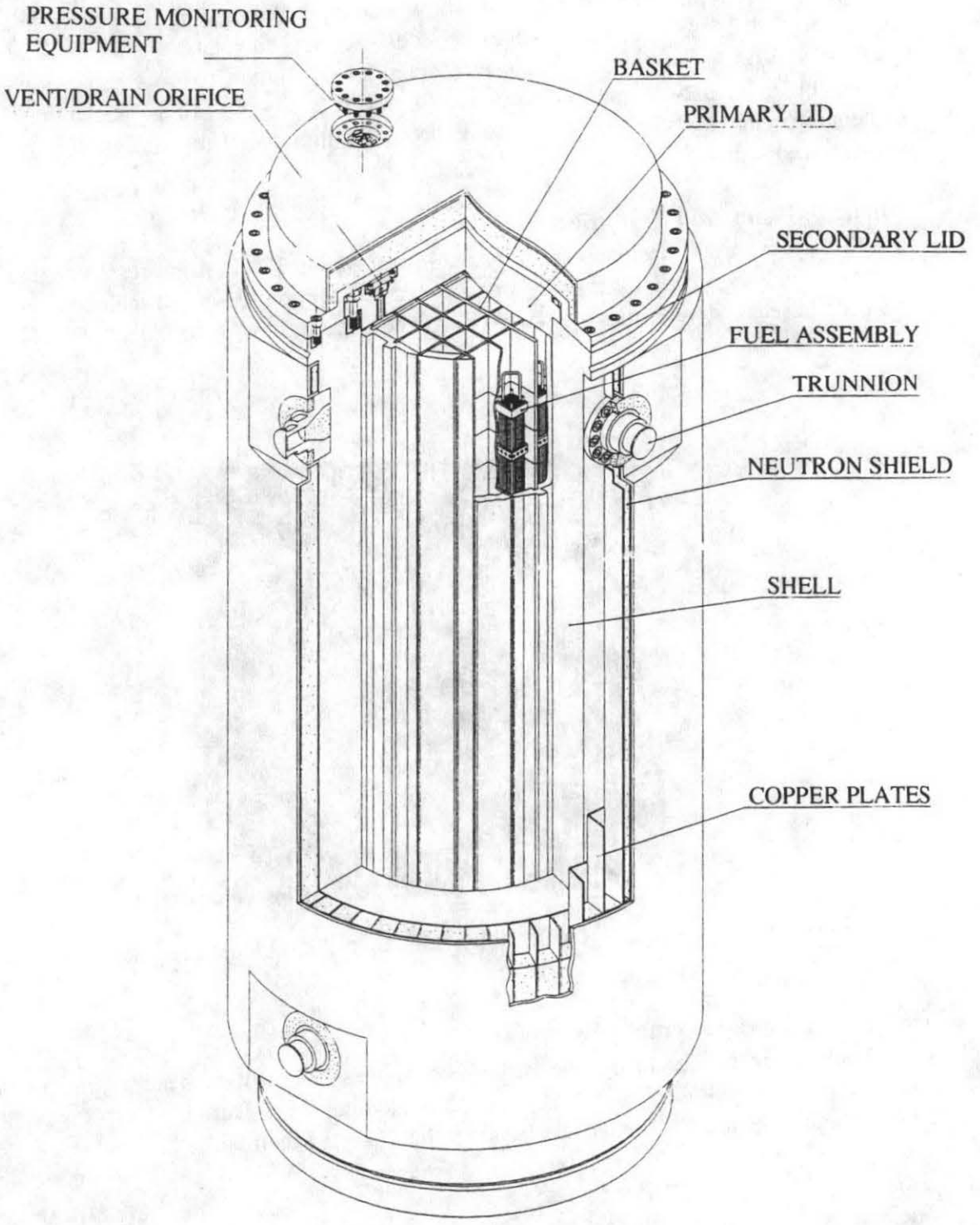

Figure 1. TN24 storage packaging

FABRICATION

Utilizing design and fabrication know-how acquired through the production of the prototype and 2/5-scale models, Kobe Steel designed and fabricated the Japanese version of the TN24 packaging, which was later adopted for use by the Tokyo Electric Power Co. at their Fukushima No. 1 site. The complete fabrication process of nine packagings, from material forging to final assembly, took about 22 months. The fabrication process is summarized in Fig. 2.

Shell, Bottom and Trunnion

These parts were all machined from material forged by a 13,000-ton press machine. The shell material was made by ring forging, as shown in Photo 3, and machined to its final shape. These parts were inspected by NDE and certified as having no inner defect.

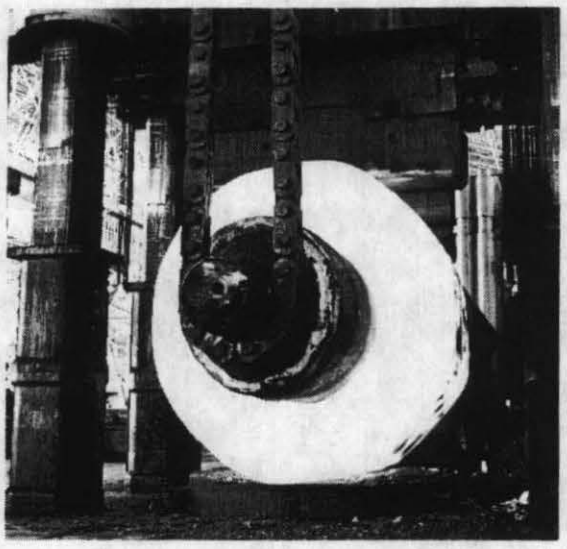

Photo 3. Forging of shell material by Kobe Steel 13,000–ton press machine

Outer Shell and Thermal Fin

Outer shells were fabricated by two carbon steel plates. These were bended semicircular shape, and L-shaped thermal fins were welded to the plate. During this process, the Kobesh neutron shields were inserted between the L-shaped thermal fins.

Body

The body was assembled from the various parts, using the following process:

- The bottom is welded to the shell.
- The NDE inspection of the welded part between shell and bottom is carried out.
- The body is heat treated.
- The body is machined to its final shape.

- The trunnion and the lid are attached to the body and a pressure test is performed.
- The two parts of outer shells with the thermal fins are attached to the body.
- The inner surface of the body is coated with metal spray, and the outer surface is first coated with the metal spray and then painted.

Lid

The lid was machined from forged material to its final shape. After forging, the material was heat treated and then inspected by the NDE and certified as having no inner defect.

Basket

The basket was assembled from the borated aluminum plates, which had been machined to the slot plate and treated with anodic oxidation. The unique grid structure of this basket ensures a high storage efficiency and an excellent anti-criticality capability.

SUMMARY AND CONCLUSION

Recently a variety of storage systems have been adopted for practical use, but the storage by package has shown itself to be superior to other systems on the following two points;

- A storage by package can store spent fuel flexibly, taking account of the amount of spent fuel to be stored, making it an economical system; and
- A main structure of the package is a robust body for fuel containment, making it a highly safe system.

These are the most important points for storage packaging of spent nuclear fuels.
Kobe Steel has now accumulated the experience of manufacture and quality control of over 100 units of the packaging.

ACKNOWLEDGMENTS

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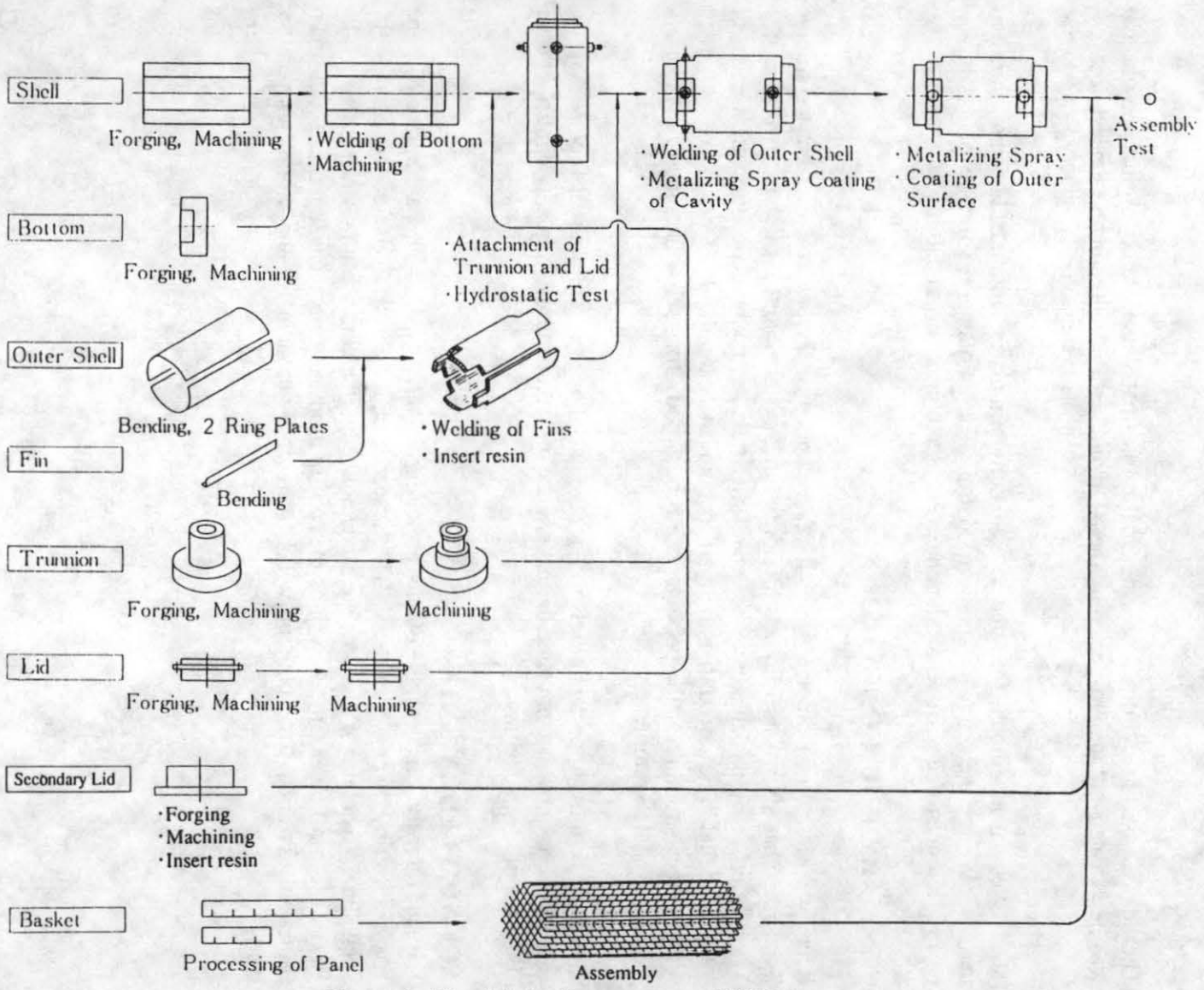

Figure 2. The fabrication process of TN24