Dry Storage Casks for Spent Nuclear Fuel - Achieving Both Safety and Economy -

Nuclear Plant Component Designing Department, Nuclear Energy Systems, Mitsubishi Heavy Industries, Ltd.

With the progress of restarting nuclear power plants that have undergone safety checks, in addition to the continued decommissioning of nuclear power plants that have been operating for many years, a considerable amount of spent nuclear fuel will be generated. Therefore, taking measures to deal with spent nuclear fuel is an important task, and activities toward dry storage using highly-safe transport/storage casks (dry casks) are being promoted. This report presents that Mitsubishi Heavy Industries, Ltd. (MHI), as a comprehensive nuclear power manufacturer, can provide a variety of dry casks according to the fuel type and customer needs, including the dry casks that we have developed and have been approved by the regulatory authorities, in order to contribute to the early realization of safe and secure dry storage.

1. Features of dry casks

Our dry cask (MSF cask : Mitsubishi Spent Fuel cask) was developed for the safe and economical interim storage of spent nuclear fuel generated from domestic nuclear power plants. The MSF cask is designed to meet both transportation and storage requirements (Regulations for the Safety Transport of Radioactive Material published by IAEA , site-specific design conditions, etc.). **Figure 1** shows an overview of the MSF cask. The main features of this cask are as follows:

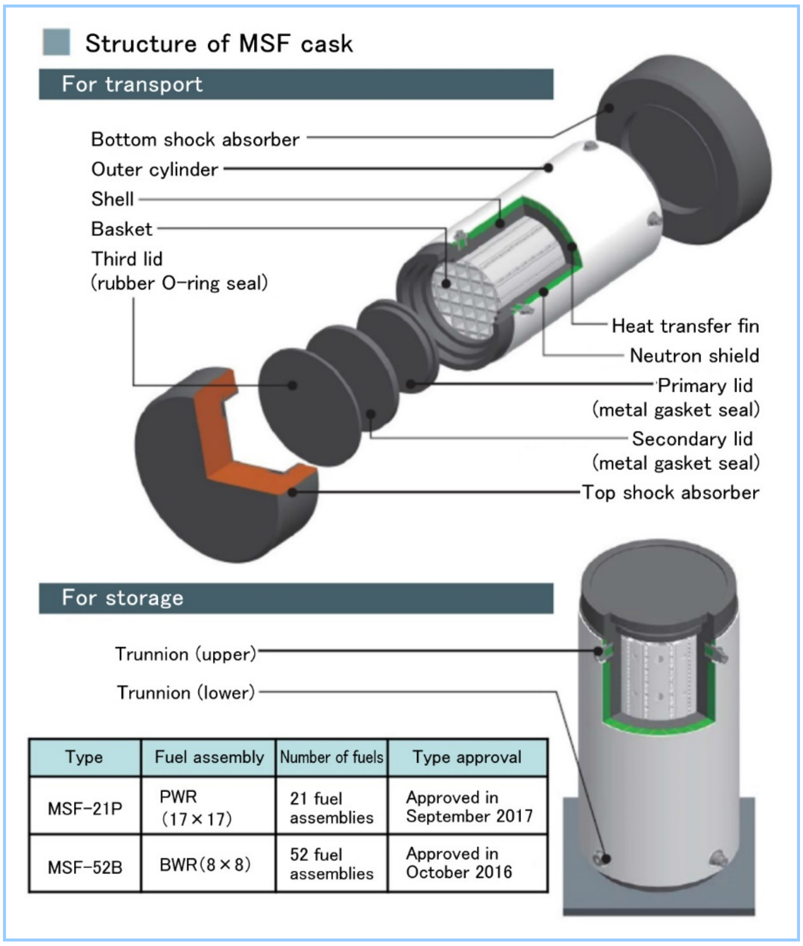
(1) Safety verification using full-scale drop test model

Using a full-scale drop test model, which is a prototype model of the MSF cask, the 9.3 m drop test (slap down and vertical drop) and 1 m penetration test specified in the IAEA Transport Regulations, which are regulated assuming the transportation accident, were conducted to verify the integrity of the sealing and structure of the dropped cask. Analysis and verification were performed leveraging the acquired data such as acceleration and strain to establish an analysis method for actual cask design. The highly-safe prototype design verified by this test was expanded to the design of the MSF cask (**Figure 2**).

In addition, as knowledge obtained from the full-scale drop test, it was found that just when the cask body falls and collides with the ground, the internal contents (fuel and basket) collide with the cask body after a time delay, resulting in an increase in the impact load which act on the internal contents. The basket has a structure that does not allow for plastic deformation so that subcriticality can be maintained even when the increase in the impact load is taken into consideration (**Figure 3**).

(2) Verification of long-term integrity

Aluminum alloy is used as the basket material for the PWR (Pressurized Water Reactor) fuel dry cask. It is generally known that the creep strength of aluminum alloys decreases in high temperature environments. Therefore, when applying this material to a basket for a cask, it is necessary to properly consider the strength of the material under the thermal history during storage. As such, we independently proposed and verified a method for evaluating the strength of aluminum alloys when exposed to high temperatures for a long period of time and confirmed the long-term integrity as the basket material (**Figure 4**). In addition, the long-term safety of neutron shielding materials and metal gaskets was confirmed by long-term heat resistance tests.



Type	Fuel assembly	Number of fuels	Type approval
MSF-21P	PWR (17×17)	21 fuel assemblies	Approved in September 2017
MSF-52B	BWR (8×8)	52 fuel assemblies	Approved in October 2016

Figure 1 Outline drawing of MSF cask

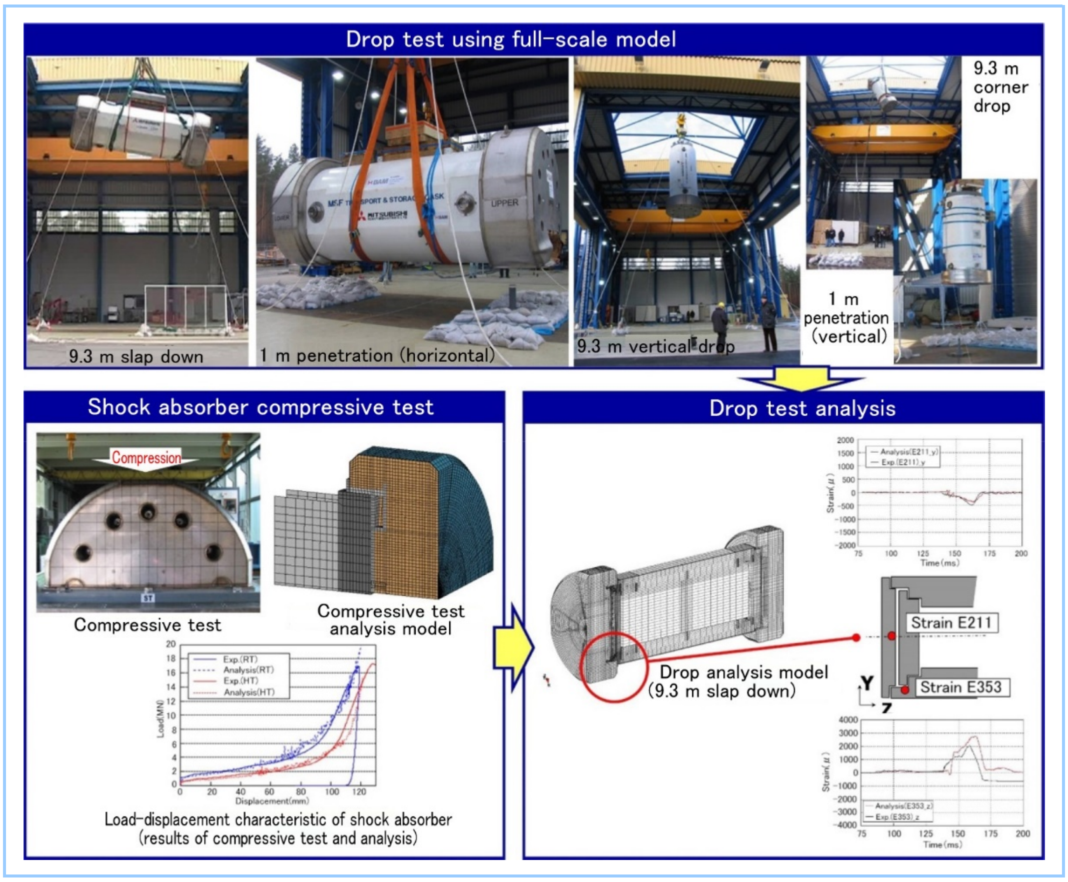


Figure 2 MSF cask safety verification test

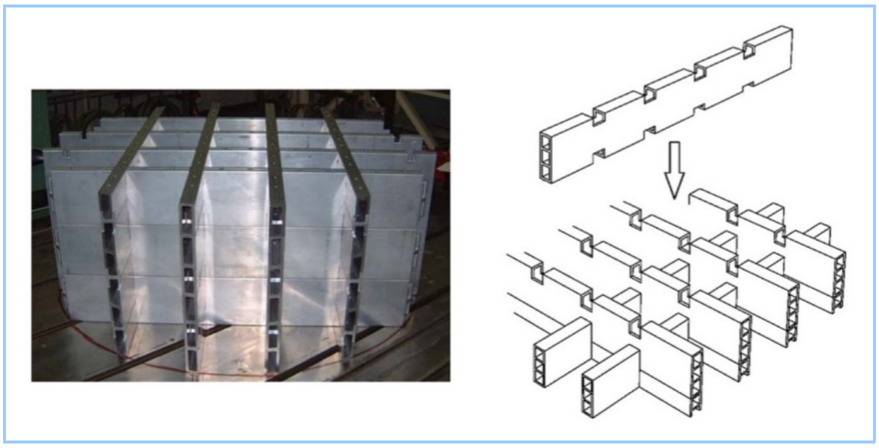


Figure 3 Structure of PWR basket

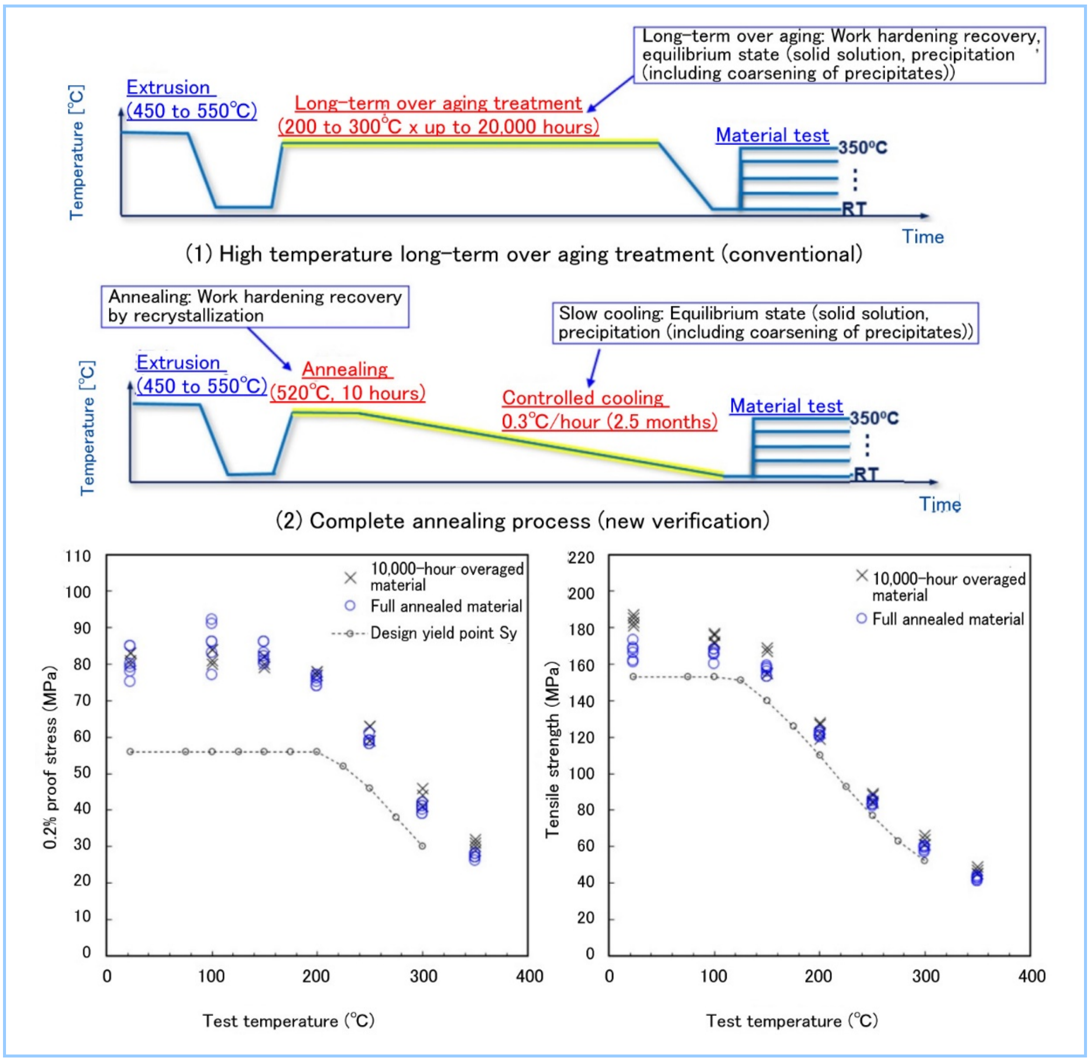


Figure 4 Heat treatment method for high-temperature-exposed aluminum basket material and test results

2. Product lineup

MHI has a wide lineup of products to meet the need for the dry storage of spent nuclear fuel stored in nuclear facilities (**Table 1**).

We developed the MSF-52B type that can store 52 BWR (Boiling Water Reactor) fuel assemblies and the MSF-21P type that can store 21 PWR fuel assemblies for interim storage facilities outside the premises of nuclear power plants, and obtained their type approvals (Note 1) for the first time as a domestic manufacturer. We have also developed the MSF-69B type that can store 69 BWR fuel assemblies and the MSF-24P/32P type that can store 24/32 PWR fuel assemblies.

The type certification of the MSF-24P is pending for spent fuel dry storage facilities on site of nuclear power plants. It has been decided that Shikoku Electric Power Co. Inc. will adopt the MSF-24P/32P type and Kyushu Electric Power Co. Inc. will adopt the MSF-21P/24P type.

(Note 1) Type approval system stipulated in " Regulations for Spent Fuel Storage"

Table 1 Specifications of MSF cask lineup

Type (Note 1)	MSF-52B	MSF-69B	MSF-21P	MSF-24P	MSF-32P
Fuel type	8×8 BWR	8×8 BWR	14×14 PWR 17×17 PWR	15×15 PWR 17×17 PWR	14×14 PWR
Number of fuels	52	69	21	24	32
Cooling period (years)	≧12	≧20	≧15	≧15	≧15
U-235 enrichments (%)	3.7	3.7	4.9 (14×14) 4.2 (17×17)	4.2	4.2
Maximum burnup (GWd/t)	50	50	55 (14×14) 48 (17×17)	48	48
Heat load (kW)	13.7	13.2	13.9	15.8	14.8
Weight (ton) (Note 2)	116 / 132.1*	116.9 / 135.0*	116.6 / 131.2*	117.7 / 134.4*	116.6 / 135.5*
Dimensions (m) (Note 3)	ϕ 3.6×6.9*	ϕ 3.6×7.2*	ϕ 3.6×6.8*	ϕ 3.6×6.8*	ϕ 3.6×6.8*

Note 1: MSF-XXB/P (MSF: Abbreviation of Mitsubishi Spent Fuel Cask, XX: Number of fuels, B/P: Fuel type)
Note 2: Weight and dimensions marked with "*" include transport shock absorbers.

3. Introduction of dedicated mass production equipment

In order to manufacture MSF casks with stable quality, MHI has introduced dedicated cask mass production equipment, enabling centralized and integrated production including welding, machining and assembly. By adopting automatic welding devices for stainless overlay welding of the body shell flange and for welding the heat transfer fins on the body shell, the time required for these manufacturing processes has been significantly reduced, and as a result, we can produce more than 20 units per year.

[1] Stabilization of quality
- Improving efficiency and reproducibility by automating welding, etc.
- Improving proficiency through centralized manufacturing and inspection

[2] Improvement of economic efficiency
- Optimizing product flow line
- Realizing labor saving and shortest construction period

[3] Stabilization of supply
- IT production management, reliable delivery date management

4. Activities for dry storage facilities

We not only design dry casks, but also design dry storage facilities based on the various technologies of our company as a nuclear plant maker. We establish optimal layout design through safety assessments on shielding and heat removal of storage facilities (**Figure 5**), and also confirmed through the manufacture of an actual equipment model that the dry casks carrier and fixing system can attain high operability by leveraging its handle ability and maintainability in the facility. The design concept of the dry storage facility requires safety, license obtainability, operability and maintainability focusing on dry casks, and we can make flexible proposals to meet customer needs.

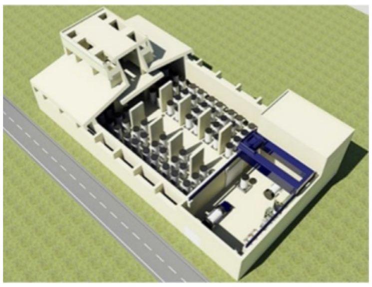


Figure 5 Bird's eye view of a dry storage facility

5. Future prospects

We have integrated the safety verification based on the drop tests, material development, safety evaluation technology and manufacturing technology that we have been working on into our MSF casks, and are able to provide products offering high safety, quality and economic efficiency. We are also working on the basic design of dry storage facilities that store dry casks. We will continue to contribute to the promotion of the dry storage of spent nuclear fuel by utilizing our comprehensive strength as a nuclear plant manufacturer.