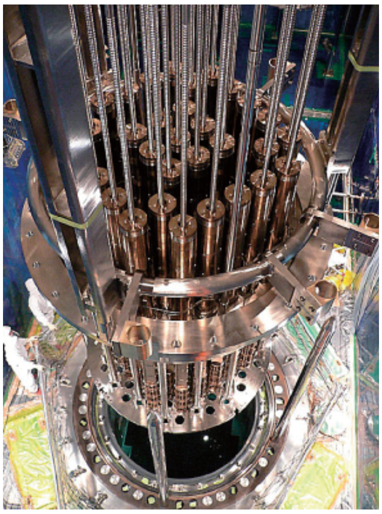

# World's First All-In-One-Piece Extraction And Replacement Work Of PWR Reactor Internals

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## 1. Introduction

Mitsubishi Heavy Industries, Ltd. (MHI) completed replacement work of the upper and lower reactor internals (**Fig. 1**) of Shikoku Electric Power Company's Ikata Unit No.1. This milestone marks the world's first replacement work of its kind in a pressurized water reactor (PWR). The same reactor internals replacement works of the Genkai Nuclear Unit No. 1 and Ikata Unit 2 were finished following Ikata Unit 1. The replacement was executed to accommodate the increased number of control rods needed for the use of high burn-up fuel, and to improve reactor equipment reliability and to have measures for preventive maintenance in order to prevent damage of baffle former bolts, of the kind reported overseas, which was caused by stress corrosion cracking (SCC).

In the first half of the operations, all of the reactor internals having over 20 years operational experience were replaced according to a new method that enabled extraction of the existing reactor internals in one piece in air, without splitting or cutting. In the second half of the operations, the new reactor internals with structures of the latest design of the Japanese standard 2 loop were installed in a reactor vessel (RV) filled with water including the smallest gap equivalent to what was needed during initial construction of the plant.

## 2. The first operation in the world

There are several cases of replacing boiling water reactor (BWR) shrouds, but no replacement of all reactor internals for a PWR has been reported.

The operation at Ikata Unit 1 is the first case anywhere in the world in which all reactor internals were replaced using a state-of-the art all-in-one extraction method (described below).

## 3. All-in-one-piece extraction method and storage cask

MHI developed a new method for removal, carrying out, and transport of the old reactor internals in order to achieve minimum radiation exposure and shorter period of operation. In the "all-in-one-piece extraction method" shown in **Fig. 2**, both upper and lower internals are directly removed as one piece in air from the RV.

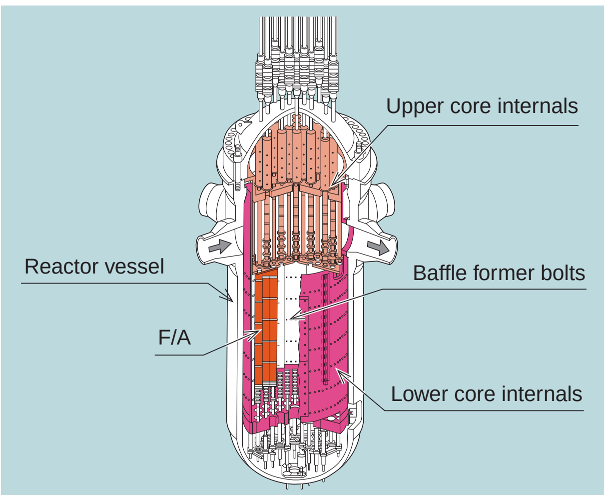


**Fig.1 PWR reactor internals**

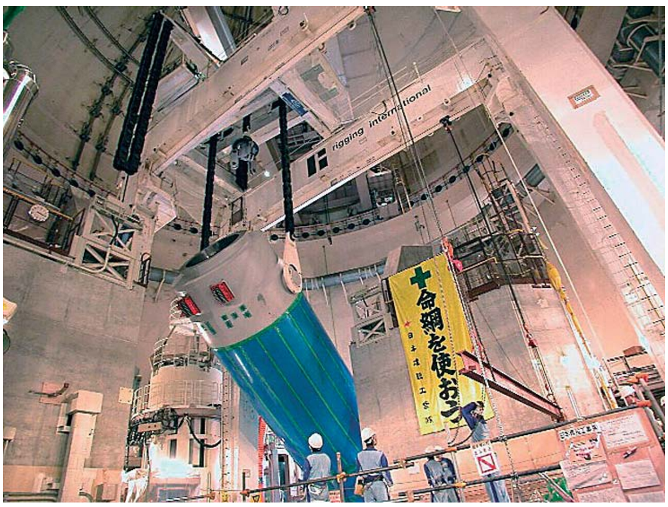

**Fig. 2 The special crane and the storage cask in the reactor containment vessel**

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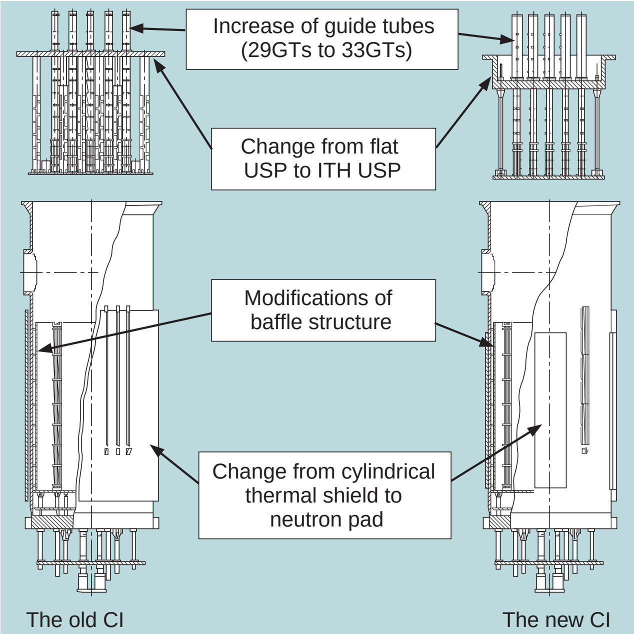


**Fig. 3 Improved structures of the new CI**

The all-in-one extraction method is composed of original techniques in a method to bring out the old reactor internals and to bring in the new reactor internals through an equipment hatch of the reactor containment vessel (CV), a method to lift up heavy weight over the capacity of the CV polar crane, a remote closing technique of the storage cask bottom plate in air, and the storage cask design itself. The method in air without decontamination of the storage cask properly contributed to lower radiation exposure and a shorter period of operation.

Dimensions of the storage cask corresponding to the all-in-one extraction method were approximately 12 m in height, 3.8 m in outer diameter, thickness of approximately 28 cm, and weight of approximately 450 t including the old reactor internals.

The cask had to be designed and manufactured with high precision due to the various requirements of the all-in-one extraction method. For example, a cask with cylindricality within 3 mm of the body inside over the whole height was manufactured so that the old reactor internals could be lifted into the cask accurately from the RV under the condition in which there were no RV guide studs.

Before actual operation, setting up of the storage cask and the special crane were finished in the MHI Kobe Shipyard & Machinery Works, where verification testing and training were conducted.

The applied all-in-one extraction method not only shortened the replacement time to 70 days (one-third of the period compared with a cutting method) but it also substantially reduced worker exposure to approximately one-tenth of what they would have been exposed to if the cutting method had been implemented.

## 4. Reactor internals design and high accuracy installation

The new reactor internals were designed and manufactured based on the latest design of Japanese 2 loop standard reactor internals as illustrated in **Fig. 3**. The features of the design were a standard design such as an inverted top hat type of upper support plate and panel type neutron pad with reduced width, and modified guide tubes and modified baffle structures.

Adopting countermeasures against three causes of the SCC, that is, stress reduction, better material and environment improved the baffle structure. The L-type baffle plate applied to the convex corner in the baffle section was adopted so that a lower number of baffle former bolts and elongation of the bolt shank could be achieved. The new reactor internals were manufactured by advanced techniques and efficient facilities in the MHI Kobe Shipyard & Machinery Works.

The old reactor internals had been installed in the RV at the initial plant construction by means of measuring gaps between the vessel and the internals by hand. When the new reactor internals were set in the water-filled RV, extremely high accuracy was necessitated, the same as the requirement during the initial construction, because of the severe restriction on bypass flow and to maintain the structural integrity of the reactor internals during seismic events.

To fulfill that requirement, MHI developed a new high precision remote-controlled measurement and installation system for underwater applications. Finally, the smallest gap of approximately 0.4 mm between the vessel and the internals equivalent to what was needed during the initial construction of the plant was accomplished with the system.

## 5. Next Steps

MHI will leverage its experience and technology applied at these power plants to continue pursuing preventive maintenance for nuclear reactor equipment, as a way of supporting the safe operation of nuclear power plants worldwide.



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