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September 5, 2012

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Attention: Mr. Jeffrey A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-12251

Subject: **MHI's Amended Response to US-APWR DCD RAI No. 374-2446 Revision 0 (SRP 03.09.05)**

Reference: 1) "Request for Additional Information No. 374-2446 Revision 0, SRP Section 03.09.05 – Reactor Pressure Vessel Internals, Application Section: DCD, Tier 2 – Section 3.9.5", dated February 21, 2009

2) "MHI's Response to US-APWR DCD RAI No. 374-2446", UAP-HF-09387, dated July 17, 2009.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Amended Response to Request for Additional Information No. 374-2446 Revision 0."

Enclosed is the amended response to Question 03.09.05-10 contained within Reference 1. MHI amends the previous response to the question transmitted in Reference 2 to incorporate additional information related to the Reactor Pressure Vessel design based on discussions with the NRC staff.

Please contact Mr. Joseph Tapia, General Manager of Licensing Department, Mitsubishi Nuclear Energy Systems, Inc. if the NRC has questions concerning any aspect of this submittal. His contact information is provided below.

Sincerely,

Y. Ogata

Yoshiki Ogata,
Director- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. Amended Response to Request for Additional Information No. 374-2446 Revision 0

D081
NRO

CC: J. A. Ciocco
J. Tapia

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Enclosure 1

UAP-HF-12251
Docket No. 52-021

Amended Response to Request for Additional Information No. 374-2446 Revision 0

September 2012

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

9/5/2012

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 374-2446 REVISION 0**
SRP SECTION:	**3.9.5 – REACTOR PRESSURE VESEL INTERNALS**
APPLICATION SECTION:	**03.09.05**
DATE OF RAI ISSUE:	**5/21/2009**

QUESTION NO.: 03.09.05-10

The DCD Tier 2, Subsection 3.9.5.3.4 includes the potential effects of irradiation stress relaxation in the list of environmental effects on reactor core internal materials caused by long term exposure to fast neutron irradiation. The applicant stated that neutron fluence and temperature limits are imposed on the tie-rods to preclude excessive loss of preload from irradiation stress relaxation.

The staff reviewed the DCD but did not find where the applicant had provided an evaluation of the loss of preload in various threaded fasteners due to irradiation stress relaxation or a reference where this information is available. The applicant did not identify the fasteners where the effect of irradiation stress relaxation is expected to be significant. Also, it is not clear how the pre-stress will be maintained in the preloaded components such as the ring block tie-rods or guide tube hold-down bolts. The applicant is requested to provide an assessment of the potential loss of preload due to irradiation stress relaxation in various threaded fasteners, in particular the guide tube hold-down bolts, guide tube support pins and the flexible leaves, and the neutron reflector tie-rods, and examine its effect on the structural and functional integrity of the components. Alternately, provide a reference document where this information is available. The requested information will assure conformance with GDC-1 and 4. Revise the DCD to include the requested information or provide a reference where this information is available.

ANSWER (Revision 1):

Assessment of the loss of preload on the various threaded fasteners due to irradiation stress relaxation had been performed based on the EPRI MRP-175 as discussed in the response to RAI Question 4.5.2-25.

Following two conclusions were obtained as the results of that assessment.

1. The neutron dose on the tie rod is comparable to the neutron reflector ring block, and the preloaded tension on the tie rod is assumed to decrease in a period of 60 years. The function of the tie rod is to restrain the vertical lift-off displacement of the neutron reflector

during seismic and LOCA events. Preload of the tie rod is reduced as a result of irradiation generated during normal plant operation. However, the tie rod is designed to ensure that some preload is left at the end of plant life. The functional requirement of the tie rod is met as long as preloaded tension still remains at the end of plant life. To minimize neutron fluence as low as possible for higher reliability, the tie rods are placed near the outside of the neutron reflector.

2. The neutron doses on various threaded fasteners are much smaller than those on the neutron reflector tie rod, and the potential loss of preload tension is small.

Impact on DCD

DCD Subsection 3.9.5 will be revised incorporated with this RAI response as shown in the Attachment to this response.

Impact on Topical/Technical Report

There is no impact on the Topical/Technical Report.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

experience with similar RV level instrumentation support tubes in 4-loop plants gives confidence in the structural and functional design.

For the thermo-couple and ICIS, the upper core support columns are used as the guide structures in the upper plenum. These structures are similar to the upper support columns in the existing 4-loop reactor design.

The US-APWR upper core plate and its interface with the fuel assemblies, core barrel, upper support columns, and lower guide tubes are not different from those of the existing 4 loop design. So, there is little impact on the flow-induced vibration due to the structural design changes around the upper core plate. More detail about the design differences between the US-APWR reactor internals and current 4 loop and effects on flow-induced vibration are described in Chapter 2.1 of Reference 3.9-22. DCD_03.09.05-30

3.9.5.1.2 Lower Reactor Internals Assembly Design Arrangement

Figure 3.9-6 shows the lower reactor internals assembly design arrangement. The major sub-assemblies of the lower reactor internals assembly are the core barrel assembly; the lower core support assembly; the neutron reflector assembly; irradiation specimen guide assembly; and the secondary core support assembly.

The core barrel assembly consists of a forged flange that is welded to the upper core barrel. The upper core barrel is welded to the lower core barrel. The core barrel flange has flow nozzles that are welded to the flange and provides a cooling flow from the RV annulus to the RV head plenum. Lifting of the core barrel assembly is accomplished by threading the lifting fixtures into the roto-lock inserts in the flange. The head and vessel alignment pins are bolted to the flange to provide guidance for the core barrel assembly during installation and removal. The head and vessel alignment pins are guided and aligned by slots in the RV and RV head. The flange has holes for access to the irradiation specimens. The upper core barrel has four welded core barrel outlet nozzles to provide an exit flow path to the RV outlet nozzles. In addition, four safety injection pads are attached to the core barrel to divert the safety injection flow from directly impinging on the barrel during a safety injection event. The lower core barrel receives the most neutron fluence from the core during normal operation. The lower core barrel has irradiation specimen guides that are fastened to the outside of the core barrel at specific locations.

The lower core support assembly consists of a lower core support plate, six radial support keys, and fuel alignment pins. The lower core support plate is welded to the lower core barrel. The lower core support plate has orificed flow holes to reduce mal-distribution of the flow into the core. Six radial keys are attached to the outside rim of the lower core support plate. These keys engage the RV clevis inserts. The keys and clevis inserts provide alignment during installation, resistance to vibration from flow, and transmit asymmetric flow loads and dynamic loads from seismic and postulated LOCA forces to the reactor vessel. The lower core support plate supports the fuel assemblies and has two fuel alignment pins per fuel assembly for alignment and horizontal restraint of the bottom fuel nozzle. The fuel alignment pins are attached to the top of the lower core support plate and restrained by a locking device.

Figure 3.9-9 shows ~~T~~the neutron reflector assembly, which offers a significant reduction in the number of threaded fasteners, and an improvement in neutron reflectivity, from the DCD_03.09.05-10 S01 design of currently operating PWR plants. The neutron reflector consists of multiple stacked ring blocks ~~that~~ whichare ~~supported~~mounted on the lower core support plate ~~in the vertical downward direction by the lower core support plate and by tie rods and neutron reflector mounting bolts in the vertically upward direction~~. DCD_03.09.05-10 S01

Vertical restraint for upward mechanical loads is provided by tie-rods and neutron reflector mounting bolts. The tie-rods are captured by a nut bearing on the top ring block. The tie-rods pass through holes in the blocks and are threaded into the lower core support plate. Fluence and temperature limits are also imposed on the tie-rods to preclude excessive loss of pre-load from irradiation relaxation. In addition, the bottom ring block is fastened directly to the lower core support plate by the mounting bolts. Ring blocks, excluding the bottom ring block, can be held down by their own weight in normal operating conditions, including design transients. During seismic and LOCA events, the lift-off displacement is restricted by the tie rods.

Ring block alignment pins between the stacked ring blocks provide horizontal alignment and shear restraint. The neutron reflector is aligned and attached to the core barrel by the upper and lower alignment pins. These alignment pins are inserted through the core barrel and guided into the clevises in the upper and lower flange of the neutron reflector, providing horizontal restraint for mechanical loads, similar to the upper core plate arrangement.

The inside surface of the ring blocks establishes the core cavity profile for the fuel assemblies. The small gaps between ring blocks are designed to be aligned with the fuel assembly grids. ~~The stacked ring blocks are connected to each other by ring block alignment pins mounted on their top and bottom surfaces for alignment and shear restraint. The neutron reflector upper alignment pin and lower alignment pins are guided into position by clevises attached to the core barrel. This arrangement provides horizontal restraint for mechanical loads, similar to the upper core plate arrangement.~~ The ring blocks are carefully designed with cooling holes to assure that void swelling and distortion are minimized. Bypass cooling flow is directed into the bottom ring block from holes machined in the lower core support plate. The holes in the lower core support plate are also orificed to provide a pressure drop that minimizes the pressure difference between the core and the neutron reflector flow paths. The holes are also sized to prevent debris from entering or blocking the cooling holes in the ring blocks. ~~Tie-rods provide vertical restraint for mechanical loads while the neutron reflector mounting bolts secure the bottom ring block to the lower core support plate. The tie-rods are captured by a nut bearing on the top ring block. The tie-rods pass through holes in the blocks and are threaded into the lower core support plate. Fluence and temperature limits are also imposed on the tie-rods to preclude excessive loss of pre-load from irradiation relaxation.~~ DCD_03.09.05-10 S01 DCD_03.09.05-10 S01

The irradiation specimen guides are fastened to the core barrel by long socket head cap screws (to accommodate bending). The specimen capsules inside the specimen guides are held in place by springs and a threaded cap. RV surveillance test specimens are periodically removed during ~~outage~~plant lifetime for examination of RV neutron fluence embrittlement. DCD_03.09.05-10 S01

The secondary core support assembly consists of secondary core support columns, diffuser plate support columns, a base plate, and energy absorber system. The diffuser plates are bolted to the diffuser plate support columns and those columns are fastened to experimental and operational experiences. Also fatigue strength degradation due to water chemistry conditions has likewise not been observed.

For conventional PWRs, ~~T~~the fast neutron effects resulting from irradiated assisted stress corrosion cracking has been shown to occur on former bolts of the baffle which attach in core region of reactor internals. However, the US-APWR uses a neutron reflector instead of the former baffle structure thus eliminating high stress bolts. Therefore, the potential of irradiated assisted stress corrosion cracking is very low. DCD_03.09.05-10 S01

Another environmental effect from fast neutron exposure on reactor internals is irradiation stress relaxation of threaded fasteners. The fasteners used near the core are identified in Figure 3.9-10 and have much smaller neutron doses than those on the neutron reflector tie rod. Tie rods restrain ~~T~~the US-APWR neutron reflector's vertical lift-off displacement ~~is fastened axially~~during seismic and LOCA events and are made ~~by tie rods~~ of strain hardened 316 stainless steel. Preloaded tension on the tie rod is reduced as a result of irradiation generated during normal plant operation. Because of this, the tie rod is designed to ensure that some preload is left at the end of a 60 year plant life in order to ensure that it's functional requirements are met. The neutron dose on the tie rod is comparable to that of the neutron reflector ring block and is minimized by locating the tie rods near the outside of the neutron reflector. DCD_03.09.05-10 S01

Irradiation embrittlement can cause a decrease in ductility and an increase in yield and ultimate strength over the design life of the plant. The amount of irradiation embrittlement is highly dependent on the fluence, metal temperature, and stress condition. For the materials selected for reactor internals, the reduction in ductility and the increase in yield and ultimate strength as well as the fatigue strength has not been shown to be an issue for the operating conditions of the US-APWR plant.

Gamma heating from fast neutron irradiation is accounted for in the design of the reactor internals.

The RV is subjected to fast neutron exposure. Protection from excessive fluence comes from (1) the water in the annulus between the core barrel outside diameter and the inside of the RV, and (2) the neutron reflector.

Void swelling from irradiation is a concern for materials with high dose rates. The neutron reflector ring blocks are subjected to high fluence dose rates and the ring blocks are cooled by flow inside cooling holes to minimize void swelling. This environmental issue is addressed for the US-APWR.

3.9.5.3.5 RCS Transient Design Basis

The RCS transient design basis is discussed in Subsection 3.9.1.1.

3.9.5.3.6 Reactor Internals Vibration Design Basis

The reactor internals vibration loads come from a dynamic computer model that inputs the pressure difference across components and the pump rotating speed and pump-induced vibration effects. The mechanical loads and displacements from the vibration analysis are used as input to the structural analysis of the reactor internals.

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05-10 S01

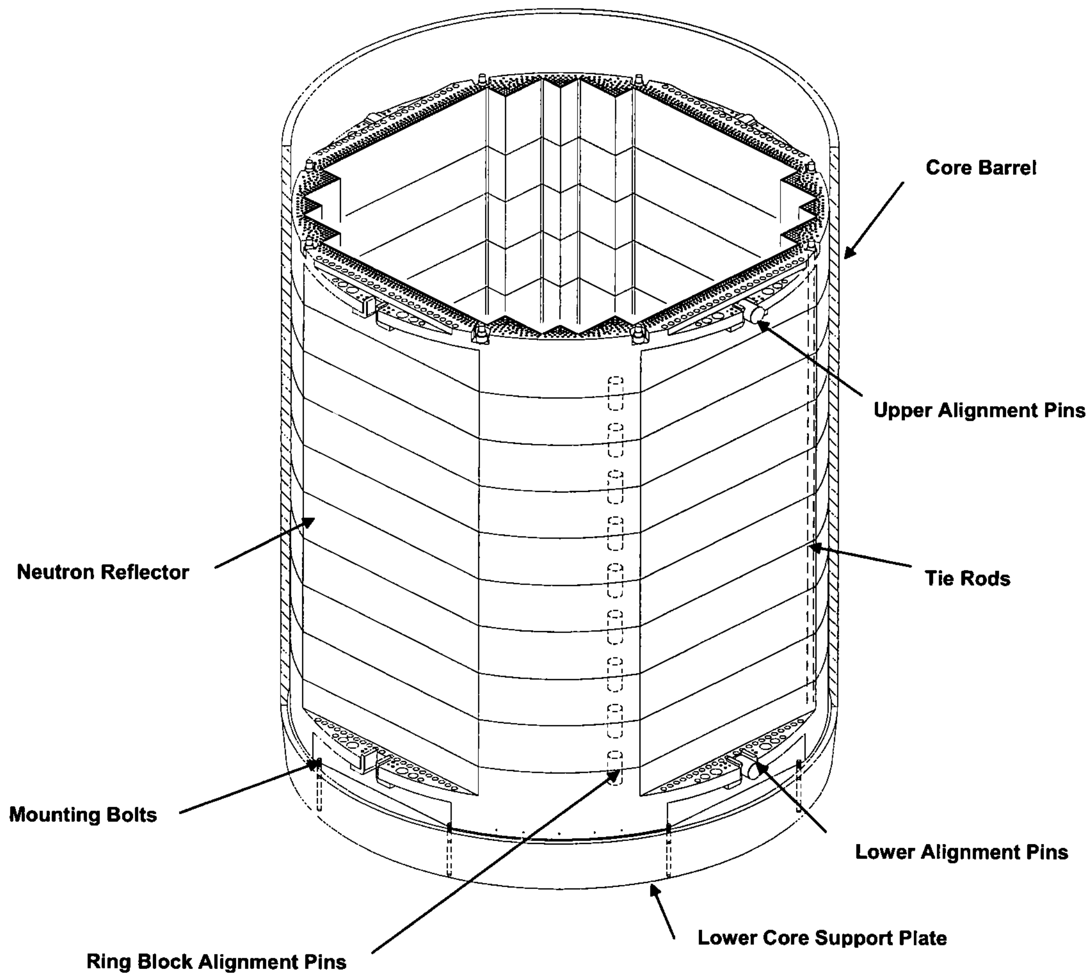

Figure 3.9-9 Neutron Reflectors

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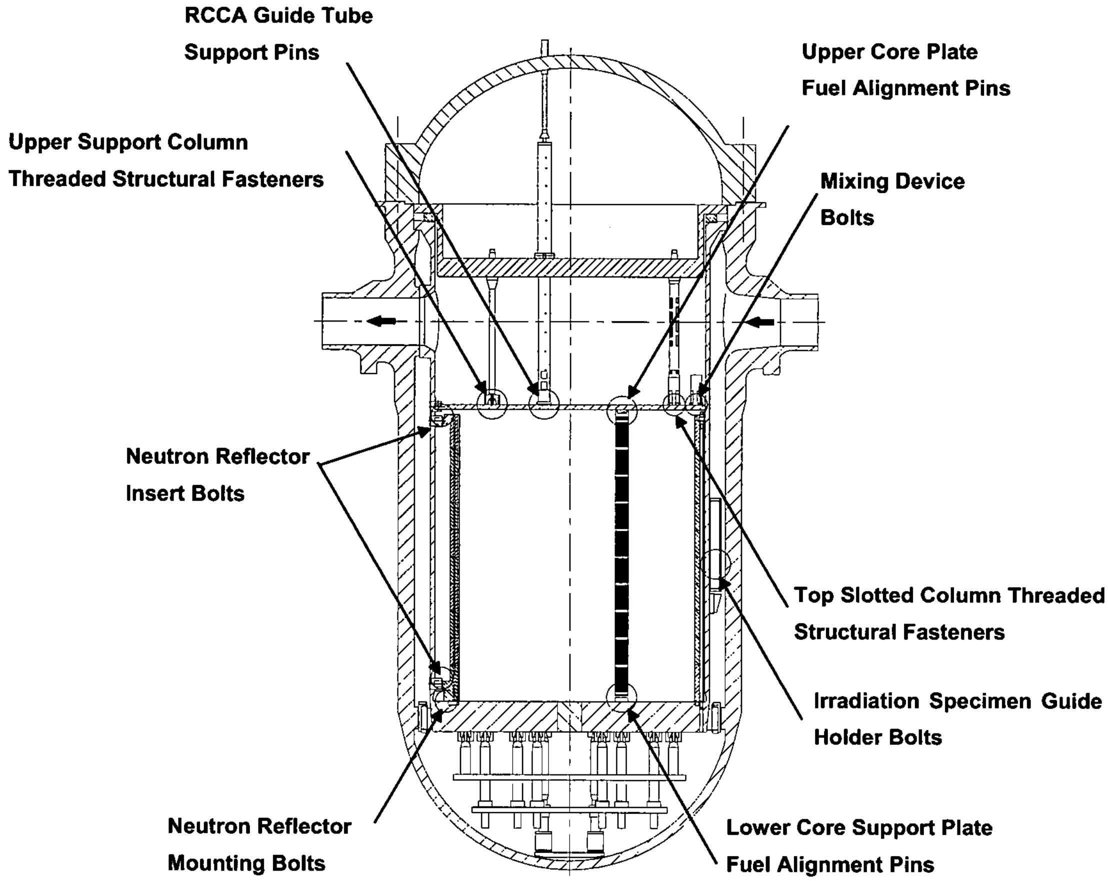

Figure 3.9-10 Fasteners around the Core