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December 19, 2013

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-13301

Subject: MHI's Response to RAI on Topical Report "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code" MUAP-07034, Revision 4

Reference: 1) REQUEST FOR ADDITIONAL INFORMATION TOPICAL REPORT FINDS: MITSUBISHI PWR FUEL ASSEMBLIES SEISMIC ANALYSIS CODE MUAP-07034, REVISION 4 dated on November 21, 2013

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "MHI's Response to RAI on Topical Report "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code" MUAP-07034, Revision 4".

Enclosed is the response to the RAI question contained within Reference 1.

As indicated in the enclosed materials, this document contains information that MHI considers proprietary, and therefore should be withheld from public disclosure pursuant to 10 C.F.R. §2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential. A non-proprietary version of the document is also being submitted with the information identified as proprietary redacted and replaced by the designation "[ ]".

This letter includes a copy of the proprietary version (Enclosure 2), a copy of the non-proprietary version (Enclosure 3), and the Affidavit of Tatsuya Hashimoto (Enclosure 1) which identifies the reasons MHI respectfully requests that all materials designated as "Proprietary" in Enclosure 2 be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

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,

T. Hashimoto for

Yoshiki Ogata,
Executive Vice President
Mitsubishi Heavy Industries, LTD.
On behalf of Mitsubishi Heavy Industries, Ltd.

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NRO

Enclosures:

1. Affidavit of Tatsuya Hashimoto

2. MHI's Response to RAI on Topical Report "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code" MUAP-07034, Revision 4 (Proprietary)

3. MHI's Response to RAI on Topical Report "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code" MUAP-07034, Revision 4 (Non-Proprietary)

CC: J. A. Ciocco
J. Tapia

<u>Contact Information</u>
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Enclosure 1

Docket No.52-021
MHI Ref: UAP-HF-13301

MITSUBISHI HEAVY INDUSTRIES, LTD.
AFFIDAVIT

I, Tatsuya Hashimoto, state as follows:

1. I am Manager, US-APWR Project of Global Nuclear Project Department, of Mitsubishi Heavy Industries, LTD. (MHI), and have been delegated the function of reviewing MITSUBISHI HEAVY INDUSTRIES, LTD's ("MHI") US-APWR documentation to determine whether it contains information that should be withheld from disclosure pursuant to 10 C.F.R. § 2.390 (a)(4) as trade secrets and commercial or financial information which is privileged or confidential.

2. In accordance with my responsibilities, I have reviewed the enclosed document entitled "MHI's Response to RAI on Topical Report "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code" MUAP-07034, Revision 4", and have determined that portions of the document contain proprietary information that should be withheld from public disclosure. Those pages containing proprietary information are identified with the label "Proprietary" on the top of the page and the proprietary information has been bracketed with an open and closed bracket as shown here "[ ]". The first page of the document indicates that all information identified as "Proprietary" should be withheld from public disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

3. The information in the report identified as proprietary by MHI has in the past been, and will continue to be, held in confidence by MHI and its disclosure outside the company is limited to regulatory bodies, customers and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and is always subject to suitable measures to protect it from unauthorized use or disclosure.

4. The basis for holding the referenced information confidential is that it describes the unique design and methodology that have been developed by MHI for the fuel of the US-APWR and are not used in the exact form by any of MHI's competitors. This information was developed at significant cost to MHI, since it required the performance of Research and Development and detailed design for its software and hardware extending over several years.

5. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of information to the NRC staff.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information. Other than through the provisions in paragraph 3 above, MHI knows of no way the information could be lawfully acquired by organizations or individuals outside of MHI.

7. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without incurring the costs or risks associated with the design of the subject systems. Therefore, disclosure of the information contained in the referenced document would have the following negative impacts on the competitive position of MHI in the U.S. nuclear plant market:

   A. Loss of competitive advantage due to the costs associated with development of the design of US-APWR fuel systems and components. Providing public access to such information permits competitors to duplicate or mimic the design of new fuel system and components without incurring the associated costs.

   B. Loss of competitive advantage of the US-APWR created by benefits of enhanced development costs associated with the design of US-APWR fuel systems and components.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information and belief.

Executed on this 19th day of December, 2013.

T. Hashimoto

Tatsuya Hashimoto
Manager- US-APWR Project
Of Global Nuclear Project Department
Mitsubishi Heavy Industries, LTD

Enclosure 3

UAP-HF-13301
Docket No. 52-021

MHI's Response to RAI on Topical Report
"FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code"
MUAP-07034, Revision 4

December 2013
(Non-Proprietary)

INTRODUCTION

This report documents the response to the NRC's Request for Additional Information (RAI) on Technical Report MUAP-07034-P(R4) "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code" dated June 18, 2013.

Background

By letter dated June 28, 2013, Mitsubishi Heavy Industries, Ltd. (MHI) submitted Revision 4 of the Topical Report MUAP-07034, "FINDS: Mitsubishi PWR Fuel Assemblies Seismic Analysis Code." The NRC staff has identified that additional information is needed to continue portions of the review.

RAI

The new Section 3.5.2, "Axial Flow Damping Effect," discusses MHI's experience with axial flow damping increase with coolant flow for 12-ft fuel assembly tests, but does not provide a specific reference to the test report. The technical references listed do provide general justification for crediting the effect of flow damping for PWR fuel, but not specifically the US-APWR design. Please provide the report which includes the MHI tests and include it as a reference in MUAP-07034-P. Also, since the US-APWR specific tests have now been completed, please include a reference to the Technical Report MUAP-13020-P, "Axial Flow Damping Test of the Full Scale US-APWR Fuel Assembly."

RESPONSE to RAI

Although Technical Report MUAP-13020-P refers to past MHI conventional 12-ft fuel assembly testing with axial flow conditions, the US-APWR Axial Flow Damping (AFD) testing is independent from the 12-ft fuel assembly AFD testing. Therefore, the descriptions of the 12-ft fuel assembly AFD testing in MUAP-07034-P will be deleted.

MUAP-13020-P(R0) "Axial Flow Damping Test of the Full Scale US-APWR Fuel Assembly" contains a detailed explanation of US-APWR axial flow damping test facility, mock-up, procedure, data reduction method, results and conclusions. The report provides a justification for crediting the effect of flow damping for US-APWR fuel assembly. Therefore, MHI will revise MUAP-07034 to include a reference to MUAP-13020 in sections 3.5.2 and 4.1.2 as shown in Attachment-1 to this response.

3.5.2 Axial Flow Damping Effect

At the reactor operating condition, much higher damping of the fuel assembly is expected to occur than for structural damping in air and hydraulic damping in still water conditions alone, due to axial coolant flow. This is because the vibration amplitude is suppressed with axial coolant flow due to the hydraulic drag force which affects cylinders such as the fuel rods in the assembly.

Delete

~~MHI has previous experience with conventional 12ft fuel assembly tests which showed that the damping factor increased with axial coolant flow (Hereafter, Axial Flow Damping (AFD)). The US APWR fuel assembly is expected to show an increasing damping factor with increased axial coolant flow.~~

As described in Reference 4, when a cylinder vibrates in flowing, viscous fluid, the fluid-dynamic forces acting on the moving cylinder are influenced by the fluid properties, including the axial flow velocity. The cumulative ~~AFD~~ effect can be calculated by accounting for these differential forces on a cylinder, and extending this concept throughout the length of the fuel rod, and fuel assembly. This process results in a free vibration equation which can be applied to express the vibration characteristics of the fuel assembly, the process is shown below.

Replace with:
"Axial Flow Damping (AFD)"

(1) Free Vibration Equation Calculation

Figure 3.5.2-1 shows the forces that are working on a differential element of the vibrating cylinder with displacement amplitude (w), gradient (α), and axial flow velocity (U).

In the lateral direction, hydraulic drag force per unit length (F_D) is expressed by the following equation.

$$F_D = -F_N - m\frac{D^2 w}{Dt^2} + \frac{\partial}{\partial x}\left(T\frac{\partial w}{\partial x}\right) \quad \cdots \quad (3.5.2\text{-}1)$$

Where,

F_N: Hydraulic drag force in the normal direction
T: Tensile force such as lift force in the fuel assembly
m: Mass per unit length
D: Substantial derivative
w: Vibration amplitude
x: Axial coordinate
t: Time

The dominant force in the right hand side (F_N) can be expressed as follows.

$$F_N = \frac{1}{2}\rho D_e U C_f\left(\frac{\partial w}{\partial t} + U\frac{\partial w}{\partial x}\right) \quad \cdots \quad (3.5.2\text{-}2)$$

Where,

U: Axial flow velocity
w: Vibration amplitude
ρ : Fluid density
D_e : Cross section diameter of the cylinder
C_f : Drag coefficient of the cylinder which includes dynamic coefficient of the viscosity of the fluid

The hydraulic drag force in longitudinal direction (F_L) can be expressed as follows.

$$F_L = -\frac{\partial T}{\partial x} \quad \cdots \quad (3.5.2\text{-}3)$$

In Equation 3.5.2-1, the last term in the right hand is negligibly small due to the fuel assembly's axial stiffness, therefore the equation can be simplified as shown below.

$$F_D = -\frac{1}{2}\rho D U c_f \left(\frac{\partial w}{\partial t} + U \frac{\partial w}{\partial t} \right) - m \frac{D^2 w}{D t^2} \quad \cdots \quad (3.5.2\text{-}4)$$

By considering this F_D and extending the same concept to the overall length of the fuel rods in the fuel assembly, the free vibration equation shown below can be applied to express the vibration characteristic of the fuel assembly in the pluck test under axial flow condition (Hereafter, AFD test).

$$M\ddot{X} + C\dot{X} + KX = F_0 - F_D \quad \cdots \quad (3.5.2\text{-}5)$$

where

X : Displacement amplitude of the fuel assembly
M, C, K : Mass, damping and stiffness of the fuel assembly
F_0 : Initial force needed to create the fuel assembly's initial displacement in the pluck test

The vibration characteristic of the fuel assembly shown in Equation 3.5.2-5 is examined in the AFD test. The obtained frequency and damping factors determined in the test are used to determine the characteristic of the FINDS model with AFD effect.

(2) Temperature Dependency

Delete

If modeling the reactor operating condition, ~~the~~ AFD effect may vary slightly due to temperature dependency. ~~The conventional 12ft fuel assembly test results showed slight temperature dependency, as described in Reference 5.~~ connect to the next paragraph

The AFD effect depends on both water density and dynamic coefficient of viscosity. Since both are temperature dependent, the AFD effect may be dependent on the water temperature. This dependency ~~will be~~ checked during the fuel assembly AFD test which ~~will use~~ the water temperature as a test parameter (Up to 150 deg. C). ~~If temperature dependency is significant, the damping factor will be appropriately extrapolated from the test condition to the reactor operating condition.~~

Replace with: "has been"

Delete

Replace with: "uses"

Add: " as described in Reference 5."

4.1.2 Axial Flow Damping Test

The objective of the axial flow damping test is to obtain a damping ratio which includes the AFD effect in an US-APWR fuel assembly mock-up.

The axial flow damping test is conducted using th
mock-up fuel assembly is installed in the fuel as
primarily of a circulation pump, test section, water st
exchanger. A constant flow rate is maintained during

Add:
" The procedure and results for US-APWR fuel assembly axial flow damping test are detailed in Reference 5."

The mock-up fuel assembly the tests are performed on is hydraulically the same as the actual US-APWR 14 ft fuel assembly: Inconel-718 top and bottom grid spacers, 9 Zircaloy-4 intermediate grid spacers, 264 fuel rods, 24 control rod guide thimbles and 1 instrumentation tube. The fuel rods were filled with lead-antimony pellets to simulate the overall fuel rod weight. The rods contained a preloaded coil spring in the upper plenum and a spacer in the lower plenum.

The test section is equipped with a displacement transducer as shown in Figure 4.1.2-2, and displacement is generated with quick [ ] equipment

The data will be used to determine damping ratio input for FINDS. The amplitude dependent inputs for the FINDS code related to frequency $\Omega(u)$ and damping $H(u)$ will be determined in the same manner with section 4.1.1. ~~Damping ratios will be extrapolated up to the reactor operating condition, if necessary.~~

Delete

7.0 REFERENCES

1. MHI, “Design Control Document for the US-APWR”, MUAP-DC020, Rev.2 October, 2009.

2. Sato et al., “The FINDS code for Fuel Seismic Analysis Considering In-elastic Impact Behaviors”, Application of Modal Analysis to Extreme Loads, ASME PVP-Vol.150, 1988, pp. 29-35.

3. H. Akiyama et al., “SEISMIC TEST AND ANALYSIS FOR PWR REACTOR CORE INTERNALS” ASME PVP-1989 Vol.182, SEISMIC ENGINEERING-1989 Design, Analysis, Testing and Qualification Methods.

4. Paidoussis, M.P., “Dynamics of Flexible Slender Cylinders in Axial Flow”, Journal of Fluid Mechanics, 1966, Part 4, pp.717-736.

~~5. Hotta et al., “Parametric Study on Parallel Flow Induced Damping of PWR Fuel Assembly”, ASME PVP Vol.191, 1990, pp. 89-98.~~

5. MHI, “Axial Flow Damping Test of the Full Scale US-APWR Fuel Assembly”, MUAP-13020, Rev.1 January, 2014.