MITSUBISHI HEAVY INDUSTRIES, LTD.
16-5, KONAN 2-CHOME, MINATO-KU
TOKYO, JAPAN

December 9, 2009

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

Attention: Mr. Jeffery A. Ciocco

Docket No. 52-021
MHI Ref: UAP-HF-09552

Subject: MHI's Responses to US-APWR DCD RAI No. 482-3655

Reference: 1) "Request for Additional Information No. 482-3655 Revision 0, SRP Section: 03.05.03 – Barrier Design Procedures, Application Section: 3.5.3," dated 11/9/2009.

With this letter, Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") a document entitled "Responses to Request for Additional Information No. 482-3655, Revision 0."

Enclosed are the responses to 2 RAIs contained within Reference 1.

Please contact Dr. C. Keith Paulson, Senior Technical Manager, 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,
General Manager- APWR Promoting Department
Mitsubishi Heavy Industries, LTD.

Enclosure:

1. Responses to Request for Additional Information No. 482-3655, Revision 0

CC: J. A. Ciocco
C. K. Paulson

Contact Information
C. Keith Paulson, Senior Technical Manager
Mitsubishi Nuclear Energy Systems, Inc.
300 Oxford Drive, Suite 301
Monroeville, PA 15146
E-mail: ck_paulson@mnes-us.com
Telephone: (412) 373-6466

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Enclosure 1

UAP-HF-09552
Docket No. 52-021

Responses to Request for Additional Information No. 482-3655, Revision 0

December, 2009

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/9/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 482-3655 REVISION 0**
SRP SECTION:	**03.05.03 – Barrier Design Procedures**
APPLICATION SECTION:	**3.5.3**
DATE OF RAI ISSUE:	**11/9/2009**

QUESTION NO. RAI 03.05.03-7:

SRP 3.5.3., "Barrier Design Procedures," provides guidance to meet the relevant requirements of GDC 2 and GDC-4. Several prediction models are available for estimating the missile impact damages for concrete materials. From a safety design point, the most critical prediction should be used as design basis.

SRP 3.5.3, SRP Acceptance Criteria, item 1B suggests Stanford Research Institute (SRI) equations developed from test data in ORNL/NSIC-5, Vol. 1, Chapter 6, by Cottrell and Savolainen for designing steel penetration thickness. Ballistic Research Laboratory (BRL) equations may be used, provided the results are comparable to those obtained by using the SRI equation or validated by penetration tests. US-APWR-DCD Section 3.5.3.1.2 suggests the use of either formula. If the BRL equation is to be used to calculate steel penetration thicknesses, provide the test data to verify its validity or confirm that the larger thickness requirement resulting from the use of either the BRL or SRI equation will be used in the design.

ANSWER:

As committed by RAI 221-1909, Question 3.5.3-03, the first paragraph of Subsection 3.5.3.1.2 was modified in DCD Revision 2 to clarify that the steel plate thickness for perforation threshold is to satisfy both BRL and SRI formulas.

Impact on DCD

There is no impact on the DCD.

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

12/9/2009

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 482-3655 REVISION 0**
SRP SECTION:	**03.05.03 – Barrier Design Procedures**
APPLICATION SECTION:	**3.5.3**
DATE OF RAI ISSUE:	**11/9/09**

QUESTION NO. RAI 03.05.03-8:

SRP 3.5.3., "Barrier Design Procedures," suggests the criteria for meeting the relevant requirements of GDC 2 and GDC-4. Several prediction models are available for estimating the missile impact damages for concrete materials. From the safety design viewpoint, the most critical prediction should be used as the design basis. As for the composite structure, the SRP further specifies that when the first barrier is concrete, procedures are reviewed on a case-by-case basis.

US-APWR DCD Section 3.5.3.1.3 (Composite Section Barrier Analysis) provides the evaluation of composite barriers for use as missile protection. SRP 3.5.3 recommends the use of composite sections as a barrier where the first layer is steel, provided that the guidance in Reference 6 of the SRP 3.5.3 is followed. Accordingly, the staff requests the following information:

- Identify, if any, and where, composite barrier protection will be provided in the barrier design.
- Clarify whether any composite barriers are utilized and where the first material is concrete, and if so, what procedures will be used in the analysis.

ANSWER:

No composite barrier protection, including where the first material is concrete, is utilized in the barrier design within the US-APWR standard plant. In the case of the steel-concrete modules, the thickness of the outer steel plates is designed to satisfy DCD Subsection 3.5.3.1.2, thereby precluding any composite barrier analysis. Therefore, DCD Subsection 3.5.3.1.3 will be revised to remove the discussion of composite barriers in the cases of extreme missile impact.

However, the process for composite barrier design permitted by SRP 3.5.3 is provided in DCD Subsection 3.5.3.1.3 to allow composite barrier protection for site-specific applications.

Impact on DCD

See Attachment 1 for the mark-up of DCD Tier 2, Section 3.5, changes to be incorporated.

- Delete the following sentence from the first paragraph in Subsection 3.5.3.1.3: "In cases of extreme missile impact, steel plate thicknesses may be limited and the residual velocity of the missiles is to be absorbed by concrete determined by equations presented in "Ballistic Perforation Dynamics" (Reference 3.5-13)."

- Change Reference 3.5-13 in Subsection 3.5.5 to the following:

  "3.5-13 Deleted."

Impact on COLA

There is no impact on COLA.

Impact on PRA

There is no impact on PRA.

This completes MHI's responses to the NRC's questions.

For the design of steel targets, the minimum design thickness (t_d) is given below where the perforation thickness, T_p, is obtained from BRL Formula or SRI Formula as applicable:

$$t_d = 1.25\ T_p$$

3.5.3.1.3 Composite (Modular) Sections

Composite or multi-element barriers consider the residual velocity of the missile perforating the first element as the striking velocity for the next element. For steel-concrete modular sections, the outer steel plates satisfy minimum thicknesses as determined in Subsection 3.5.3.1. ~~In cases of extreme missile impact, steel plate thicknesses may be limited and the residual velocity of the missiles is to be absorbed by concrete determined by equations presented in "Ballistic Perforation Dynamics" (Reference 3.5-13).~~

The residual velocity after missile penetration of the first layer (or outer shield) is determined by the formula:

$$V_r = \sqrt{V^2 - V_B^{\ 2}}$$

where

V_r = residual velocity after missile penetration of the first layer (or outer shield)

V = impact (or striking) velocity of the missile object

V_B = perforation velocity associated with the energy absorbed up to the threshold of perforation.

3.5.3.2 Evaluation of Overall Structural Effects

Elements required to remain elastic are evaluated to assure that the usable strength capacity exceeds the demand. For structures allowed to displace beyond yield (elasto-plastic response), an evaluation confirms that acceptable deformation limits to demonstrate ductile behavior are not exceeded by comparing computed demand ductility ratios with capacity values.

After it is determined that a missile will not penetrate the barrier, an equivalent static load concentrated at the impact area is applied in conjunction with other design loads. Refer to Subsection 3.3.2.2 for determination of tornado forces on structures, including equivalent static loads for tornado missile impact. In determining an appropriate equivalent static load for other missiles sources (as defined in Subsection 3.8.4), elasto-plastic behavior may be assumed with permissible ductility ratios as long as deflections will not result in loss of function of any safety-related system.

The flexural, shear, and buckling effects on structural members are determined using the equivalent static load obtained from the evaluation of missile impact on structural response. Stress and strain limits for the equivalent static load comply with "Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments)", RG 1.142, Rev.2 (Reference 3.5-14), and "Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities",

3.5-4 Rules for Construction of Nuclear Facility Components, American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code Section XI, 2001 Edition through the 2003 Addenda.

3.5-5 Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder), ASME NOG-1, 2004.

3.5-6 Protection Against Low-Trajectory Turbine Missiles. Regulatory Guide 1.115, Rev. 1, U.S. Nuclear Regulatory Commission, Washington, DC, July 1977.

3.5-7 Turbine Missiles, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800, Standard Review Plan, Section 3.5.1.3, Rev. 3, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

3.5-8 Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants. Regulatory Guide 1.76, Rev. 1, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

3.5-9 A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects, R. P. Kennedy, Nuclear Engineering and Design, Volume 37, Number 2, pp 183-202, 1976.

3.5-10 Barrier Design Procedures, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800, Standard Review Plan, Section 3.5.3, Rev. 3, U.S. Nuclear Regulatory Commission, Washington, DC, March 2007.

3.5-11 U.S. Reactor Containment Technology, W.B. Cottrell and A.W. Savolainen, NSIC-5, Oak Ridge National Laboratories, Volume 1, Chapter 6, 1965.

3.5-12 Reactor Safeguards, C. R. Russell, MacMillan Publishers, New York, 1962.

3.5-13 ~~Ballistic Perforation Dynamics, R. F. Recht and T. W. Ipson, ASME Journal of Applied Mechanics, Volume 30, Series E, Number 3, September 1963.~~ Deleted.

3.5-14 Safety-Related Concrete Structures for Nuclear Power Plants (Other than Reactor Vessels and Containments), Regulatory Guide 1.142, Rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, November 2001.

3.5-15 Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities, including Supplement 2 (2004), ANSI/AISC N690-1994, American National Standards Institute/American Institute of Steel Construction, 1994 & 2004.

3.5-16 Code Requirements for Nuclear Safety-Related Concrete Structures, American Concrete Institute (ACI) 349, 1997.