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February 28, 2011

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-11052

Subject: MHI's Responses to US-APWR DCD RAI No. 686-4557 Revision 0 (SRP 03.05.05)

Reference: 1) "Request for Additional Information No. 686-4557 Revision 0, SRP Section: 03.05.03 – Barrier Design Procedures," dated 1/26/2011.

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. 686-4557, Revision 0."

Enclosed is the response to the RAI contained within Reference 1. This transmittal completes the response to this RAI.

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,

Atsushi Kumaki for

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

Enclosure:

1. Response to Request for Additional Information No. 686-4557, Revision 0

CC: J. A. Ciocco
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Enclosure 1

UAP-HF-11052
Docket No. 52-021

Response to Request for Additional Information No. 686-4557, Revision 0

February, 2011

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

2/28/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

RAI NO.:	**NO. 686-4557 REVISION 0**
SRP SECTION:	**03.05.03 – Barrier Design Procedures**
APPLICATION SECTION:	**3.5.3**
DATE OF RAI ISSUE:	**1/26/2011**

QUESTION NO. RAI 03.05.03-9:

1. RAI Text
The applicant is requested to provide a safety analysis that assesses potential damage to Seismic Category I structures resulting from a tornado-generated missile impact at ***any*** elevation above grade and any azimuthal direction. More specifically, one issue related to elevation consideration is that the non-uniform structure stiffness and thickness throughout the height of PCCV, such as the dome which has smallest thickness, or the PCCV wall in the vertical direction, which the stiffness continues to decrease from the base to the top. thus, the same impact energy applied to different elevation will induce different global structural responses and localized damage. Moreover, higher elevation impact momentum can induce higher overturning moment for the PCCV building. In order for the NRC staff to verify compliance with requirements in GDC-2 in Appendix A to 10 CFR Part 50, the applicant is requested to address the following two types of damage in the analysis and to provide technical evidence that the potential impacts from each type of missile within the applicant's design-basis tornado missile spectrum do not compromise the structural integrity of any Seismic Category I structure or adversely affect its ability to perform its intended safety functions.

(1) Local damage:
- (a) full penetration of missile "punch-thru" due to shear failure
- (b) crack initiation and propagation due to partial penetration at a building location under highest stress

(2) Global damage:
- (a) building "tip-over" or "sliding" due to foundation failure
- (b) failure of critical section due to severe impact/dynamic loads

The applicant is also requested to include as part of the analysis a description of the physical characteristics, the maximum speed, and the envelope of potential impact locations (i.e., SSC identifier, elevation above grade, and corresponding azimuthal direction) for each type of missile included in the applicant's design-basis tornado missile spectrum.

2. Concern
Compliance with GDC 2 requires that nuclear power plant SSCs important to safety are designed to withstand the effects of natural phenomena such as earthquakes, tornadoes,

hurricanes, floods, tsunami, and seiches without loss of capability to perform their intended safety functions. The design bases for these SSCs are required to reflect: (1) appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed.

The design-basis tornado-generated missile spectrum in Table 2 of Regulatory Guide 1.76, Rev. 1 is generally acceptable to the NRC staff for the design of nuclear power plants. In addition, the NRC staff considers the missiles listed in Table 2 to be capable of striking in all directions with horizontal velocities of V_{Mh}^{max} and vertical velocities equal to 67 percent of V_{Mh}^{max}. According to the Rankine combined vortex model, which was used by the NRC staff as the basis for the tornado characteristics described in Regulatory Guide 1.76, Rev. 1, wind velocities and pressures are assumed not to vary with elevation, and the model possesses only azimuthal velocity. Because these Rankine combined vortex model features apply to all tornadoes, the maximum tornado missile velocity is considered by the NRC staff to be independent of the missile height above ground.

In general, the assumption made in procedure used for calculating wind pressure is that the wind velocities and, therefore, the wind pressure, do not vary with the height above the ground. Furthermore, maximum horizontal velocity spectra generated by E. Simiu are widely used in estimated maximum horizontal speed of the tornado induced missile, where the initial condition used for the calculation is assume the object is at the height of 40 meters. Regarding an automobile, the associated CdA/m index is about 0.0070 for a 4000lb weight, and the associated maximum missile velocity is independent of the missile elevation (or height). In reality, any tornado-generated missile could potentially impact an SSC from any azimuthal direction and at any elevation above grade at the maximum tornado missile velocity.

Furthermore, from a structural point of view, a higher elevation impact to the power plant shielding (dome) may have potential of generating more impact response (such as higher bending moment or more deflection relative to the base structure, etc,) than that which would occurr at a lower elevation. Moreover, the high elevation of the structure may also have less rigidity and less material mass than the lower section of the building, thus, higher elevation missile may have the potential to produce more severe local damage to the building than that of a lower elevation missile impact. In order for the NRC staff to verify compliance with requirements in GDC-2 in 10 CFR 50, Appendix A, the applicant is requested to provide information about tornado missiles including automobiles and other tornado-generated objects within the scope of the applicant's design-basis tornado missile spectrum. The applicant is also requested to provide a safety analysis that assesses potential damage to Seismic Category I structures resulting from tornado-generated missile impacts that can occur at ***any*** elevation above grade and any azimuthal direction.

3. Applicant References:
DCD Tier 2, Revision 1, Section 3.5 and Section 3.3.

4. Context
Structural integrity of Seismic Category I structures, which assures that SSCs important to safety are protected, and not compromised according to GDC-2 in the Appendix A to Part 50 of 10 CFR.

5. Priority/Impact

Medium – information is essential to completing a technical review and resolving a safety issue of PMF. The review can continue, but cannot be completed without the requested additional information.

6. Dependencies
Internal – There are interfaces with SRP Chapter 3.0, Section 3.3, and Section 3.5.
External – There are no external dependencies.

ANSWER:

US-APWR Design Control Document, Tier 2 Sections 3.3 and 3.5 include descriptions of the design controls that apply to the design of Seismic Category I structures for tornado-generated missiles. As discussed in DCD Section 3.5, missile protection for the US-APWR is in accordance with GDC 2 and GDC 4 of Appendix A of 10 CFR Part 50. The US-APWR also conforms to the guidance of RG 1.76 Revision 1, including the tornado missile spectrum that is adopted. The spectrum of tornado missiles considered is described in DCD Subsection 3.5.1.4. DCD Subsection 3.5.1.4 was revised in Revision 2 to clarify that the design of Seismic Category I structures is adequate to withstand tornado missiles that impact at any elevation above grade and any azimuthal direction, including the automobile missile. The velocity of the missiles considered does not vary with height above grade. Further clarification will be made in Subsection 3.5.1.4 on this point, as described in "Impact on DCD" below.

With respect to item (1) local damage in the RAI question:

DCD Subsection 3.5.3.1 describes the design controls applicable to local damage effects. The design methodology used for local damage is in compliance with SRP Acceptance Criteria 3.5.3 II.1A, 3.5.3 II.1B, and 3.5.3 II.1C. "Punch-thru" is prevented by ensuring that member thicknesses are equal or greater than those determined in accordance with the formulas presented in Subsection 3.5.3.1. The formulas also include factors to prevent scabbing. The thicknesses of walls and roofs also satisfy the minimum barrier thicknesses provided in Table 1 of SRP 3.5.3. DCD Subsection 3.5.3.1.1 will be revised to clarify this point as described in "Impact on DCD" below.

Crack initiation and propagation due to partial penetration at a building location under highest stress may occur. Such effects are permitted to the extent that they conform to the design controls specified in DCD Subsection 3.5.3.2 to prevent loss of function of any safety-related system. Additional design considerations for tornado missile effects are discussed in DCD Subsections 3.3.2.2.3 and 3.3.2.3. Load combinations involving tornado missiles are defined in DCD Subsection 3.3.2.2.4 and Tables 3.8.4-3 and 3.8.4-4.

Therefore, local damage due to tornado missile effects will not compromise the structural integrity of any Seismic Category I structure or adversely affect its ability to perform its intended safety functions, or the safety functions of any safety-related systems that it protects.

With respect to item (2) global damage in the RAI question:

Design for building "tip-over" and foundation sliding failure are dominated by the seismic design load combinations, not by load combinations involving tornado missiles. For example, the heaviest missile, which is the 4000 lb automobile missile, is about 0.013% of the weight of a Power Source Building, which weighs roughly 30,000,000 lb (Reference MHI Technical Report MUAP-10001, "Seismic Design Bases of the US-APWR Standard Plant", Revision 2, Table 5.4.2-1). Due to this small ratio, lateral building load due to transfer of the automobile missile kinetic energy will have negligible impact on "tip-over" and sliding. This ratio is even less for the PCCV, which weighs roughly 70,000,000 lb (shell cylinder and dome portions only) (Reference MHI

Technical Report MUAP-10001, "Seismic Design Bases of the US-APWR Standard Plant", Revision 2, Table 5.3.1-4).

The design controls specified in DCD Subsection 3.5.3.2 prevent failure of critical sections due to the severe impact/dynamic loads associated with tornado missiles. As discussed for local effects, damage due to impact is permitted to the extent that any global damage conforms to the design controls specified in DCD Subsection 3.5.3.2 to prevent loss of function of any safety-related system. The design methodology used for global damage is in compliance with SRP Acceptance Criterion 3.5.3 II.2. For example, elasto-plastic behavior may be assumed with permissible ductility ratios in the analysis as long as deflections will not result in loss of function of any safety-related system.

Therefore, global damage due to tornado missile effects will not compromise the structural integrity of any Seismic Category I structure or adversely affect its ability to perform its intended safety functions, or the safety functions of any safety-related systems that it protects.

Impact on DCD

See the Attachment 1 mark-up of DCD Tier 2, Subsection 3.5, changes to be incorporated. The changes are summarized as follows.

- Replace the last sentence of the first bullet in DCD Subsection 3.5.1.4 with the following:

  "To accommodate site-specific conditions where grades within 0.5 mile of plant structures may have elevations higher than grade at the structures, this missile is considered to potentially impact SSCs at any azimuthal direction and at any elevation above grade at the maximum tornado missile velocity stated above."

- Revise the second sentence of the first paragraph in DCD Subsection 3.5.3.1.1 to read as follows:

  "Wall and roof thicknesses satisfy minimum barrier thicknesses provided in Table 1 of NUREG-0800, SRP 3.5.3 (Reference 3.5-10) to prevent local damage against tornado generated missiles."

Impact on COLA

There is no impact on the COLA.

Impact on PRA

There is no impact on the PRA.

This completes MHI response to the NRC question.

ATTACHMENT 1
to RAI 686-4557

severe. The spectrum of missiles is chosen to represent: (1) a massive high-kinetic-energy missile that deforms on impact, (2) a rigid missile that tests penetration resistance, and (3) a small rigid missile of a size sufficient to pass through any opening in protective barriers.

Therefore, the spectrum of tornado missiles is as follows:

- A 4,000 pound automobile, 16.4 ft by 6.6 ft by 4.3 ft, impacting the structure at normal incidence with a horizontal velocity of 135 ft/s or a vertical velocity of 90.5 ft/s. To accommodate site-specific conditions where grades within 0.5 mile of plant structures may have elevations higher than grade at the structures, this missile is considered to potentially impact SSCs at any azimuthal direction and at any elevation above grade at the maximum tornado missile velocity stated above. . ~~This missile is considered to potentially impact at all plant elevations up to 30 ft above grade for all grades within 0.5 mile of the plant structures.~~
- A 6.625 inch diameter by 15 ft long schedule 40 pipe, weighing 287 pounds, impacting the structure end-on at normal incidence with a horizontal velocity of 135 ft/s or a vertical velocity of 90.5 ft/s.
- A 1 inch diameter solid steel sphere assumed to impinge upon barrier openings in the most damaging direction with a horizontal velocity of 26 ft/s or a vertical velocity of 17.4 ft/s.

Openings through the exterior walls of the seismic Category I structures, and the location of equipment in the vicinity of such openings, are arranged so that a missile passing through the opening would not prevent the safe shutdown of the plant and would not result in an offsite release exceeding the limits defined in 10 CFR 100 (Reference 3.5-2). Otherwise, structural barriers are designed to resist tornado missiles in accordance with the design procedures discussed in Subsection 3.5.3. Tornado missiles are not postulated to ricochet or strike more than once at a target location. Tornado missile protection is provided to resist the normal component of force delivered by the missile striking in any direction. Due to the robustness of the exterior wall design, all seismic Category I structures are capable of withstanding the impact of each identified tornado missile at any elevation, including the potential impact of a 4,000 pound automobile greater than 30 feet above grade.

3.5.1.5 Site Proximity Missiles (Except Aircraft)

Externally initiated missiles considered for the US-APWR standard design are based on tornado missiles as described in Subsection 3.5.1.4. As described in DCD, Section 2.2, the COL Applicant is to establish the presence of potential hazards, except aircraft, which is reviewed in Subsection 3.5.1.6, and the effects of potential accidents in the vicinity of the site. The RG followed is identified, and any deviations from this guidance or any alternative methods that are used are explained or justified. The information also describes the data collected, analyses performed, results obtained, and any previous analyses and results cited to justify any of the conclusions. Additional analyses may be required to evaluate other potential site-specific missiles.

ATTACHMENT 1
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in Section 2.2. Additional analyses may be required to evaluate po

3.5.2 Structures, Systems, and Components to be Protected from Externally Generated Missiles

Safety-related SSCs are identified in Section 3.2 and Section 3.11. Protection of these systems from external missiles is provided by the external walls and roof of the safety-related R/B and PS/B. The external walls and roofs are reinforced concrete. The structural design requirements for the R/B and PS/B are outlined in Subsection 3.8.4.

Openings through exterior walls of the seismic Category I structures are evaluated as described in Subsection 3.5.1.4 to provide confidence that a missile passing through the opening would not prevent safe shutdown and would not result in an offsite release exceeding the limits defined in 10 CFR 100 (Reference 3.5-2). The COL Applicant is responsible to evaluate site-specific hazards for external events that may produce missiles more energetic than tornado missiles, and assure that the design of seismic category I and II structures meet these loads.

3.5.3 Barrier Design Procedures

If required, components, protective shields, and missile barriers are designed to prevent damage to safety-related components by absorbing and withstanding missile impact loads. The target SSCs, shields, and barriers are evaluated for both local effects and overall structural effects due to missile impacts. The local effects in the impacted area are evaluated to predict the minimum thickness required for steel structures and for concrete structures to prevent perforation and the potential generation of secondary missiles by spalling or scabbing effects. A review of the structure for overall response is conducted to estimate forces, moments and shears induced in the barrier by the impact force of the missile.

3.5.3.1 Evaluation of Local Structural Effects

The following subsections address the design of structures to withstand and absorb missile impact loads. Formulas are provided to predict the penetration depth (x), scabbing thickness (t_s) and perforation thickness (t_p) potential created by the missile impact. Safety factors are then applied to determine required barrier thicknesses to restrict missile penetration, scabbing and/or perforation. It is assumed that the missile impacts normal to the plane of the wall on a minimum impact area and, in the case of reinforced concrete, its resistance does not credit capacity of struck reinforcing.

3.5.3.1.1 Concrete

The National Defense Research Council (NDRC) provides "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects", by R. P. Kennedy (Reference 3.5-9). ~~Selected w~~Wall and roof thicknesses ~~also~~ satisfy minimum barrier thicknesses provided in Table 1 of NUREG-0800, SRP 3.5.3 (Reference 3.5-10) to prevent local damage against tornado generated missiles.