July 28, 2011

UNITED STATES - ADVANCED PRESSURIZED WATER REACTOR ROD EJECTION ACCIDENT METHODOLOGY TOPICAL REPORT MUAP-07010 REVISION 1, "NON-LOCA METHODOLOGY," AUDIT PLAN

August 4 - 5, 2011

US-APWR DESIGN CERTIFICATION
Mitsubishi Heavy Industries, Ltd.
Docket No. 52-021

Location: Mitsubishi Nuclear Energy Systems
1001 19th Street North, 7th Floor
Arlington, VA 22209

Purpose:

The purpose of this regulatory audit is for the U.S. Nuclear Regulatory Commission (NRC) staff to gain an understanding of the methods and technical basis used in the analysis of the Rod Ejection Accident (REA) for the United States - Advanced Pressurized Water Reactor (US-APWR). This audit will in turn provide information to allow the NRC staff to confirm the technical adequacy of the REA methodology and US-APWR design compliance with applicable NRC staff requirements. The audit will focus on acceptability of the REA methodology for at-power conditions, and, in particular, the methods used to calculate the number of fuel failures due to exceeding the Departure from Nucleate Boiling (DNB) limits under certain accident scenarios.

Background:

By letter dated December 31, 2007, Mitsubishi Heavy Industries, Ltd. (MHI) submitted the US-APWR Design Control Document for the NRC staff's review and approval (Reference 1). To support this application, by letter dated July 20, 2007, and later superseded by letter dated October 29, 2010, MHI submitted licensing Topical Report MUAP-07010-P, Revision 1, "Non-LOCA Methodology," (Reference 2) for the NRC staff's review and approval. This topical report, in part, describes the methodology by which MHI analyzes the Rod Ejection Event for the US-APWR. For Hot Full Power (HFP) conditions, MHI utilizes a one-dimensional methodology using the TWINKLE-M computer code to calculate the core power transient resulting from a large reactivity insertion (Reference 1).

As demonstrated in the review of other reactor designs similar to the US-APWR (Reference 3), the limiting rod ejection scenario from a fuel failure standpoint at HFP does not necessarily result from a large reactivity insertion. While a large reactivity insertion is limiting from a prompt enthalpy deposition standpoint, it may not be limiting from a DNB standpoint. For HFP conditions, DNB is a greater concern than prompt enthalpy deposition due to relatively reduced rodworths because rod insertion is limited by the Rod Insertion Limits specified in the cycle-specific Core Operating Limits Report (COLR), coupled with reduced thermal margins relative to less than full power operation. The possibility exists for an accident scenario where a limited amount of reactivity is inserted into the core due to a rod ejection that results in a substantial power increase but does not cause the high power range neutron flux trip function of the Reactor Protection System to respond.

Therefore, the reactor core would be operated at an elevated power level during a slow depressurization for an extended period of time. These conditions are adverse from a DNB standpoint, and, in order to properly identify the limiting HFP rod ejection scenario and resultant rod failure census, should be adequately dispositioned. The staff issued a Request for Additional Information (RAI) to MHI requesting that this particular HFP REA scenario be addressed (Reference 4). By MHI's request, the disposition of Reference 4 is being addressed in the response to RAI REA-12 of Reference 5. Since the issuance of REA-12, there have been multiple teleconferences and reviews of draft RAI response information in an effort to ensure that MHI has adequately analyzed the scenario described above and conservatively determined the number of rods failed due to DNB. This audit serves as the mechanism for ensuring the NRC staff understands the basis and implementation of the methodology proposed by MHI to close the RAI and come to a reasonable assurance finding that the limiting REA scenario has been properly analyzed.

Regulatory Audit Basis:

The rod ejection accident is analyzed to demonstrate compliance with General Design Criteria (GDC) 13, "Instrumentation and Control," and GDC 28, "Reactivity Limits," as described in Appendix A to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." Section 15.4.8 of the Standard Review Plan (SRP) provides specific guidance for demonstrating compliance with the stated GDCs for rod ejection analysis. The applicable SRP criteria are:

1. GDC 13, in that the reviewer evaluates the sequence of events, including automatic actuations of protection systems, and manual actions, and determines whether the sequence of events is justified, based upon the expected values of the relevant monitored parameters and instrument indications.

2. GDC 28, in that the reviewer evaluates the maximum reactor pressure during any portion of the transient corresponding to a rod ejection. The American Society of Mechanical Engineer Codes provides guidance for the acceptability of anticipated accident pressure. The review also examines the extent of fuel damage from a rod ejection accident. Regulatory Guide (RG) 1.77, "Assumptions Used for Evaluating a Control Rod Ejection Accident for Pressurized Water Reactors," and SRP Section 4.2 provide guidance for acceptability of anticipated core damage.

In addition to these GDCs; 10 CFR 100.11, "Determination of exclusion area, low population zone, and population center distance;" and 10 CFR 50.67, "Accident source term," establish radiation dose limits for individuals at the boundary of the exclusion area and at the outer boundary of the low population zone. The fission product inventory released from all failed fuel rods is an input to the radiological evaluation under SRP Section 15.0.3. SRP Section 4.2 describes fuel rod failure mechanisms. Guidance for calculating radiological consequences is in RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," and RG 1.195, "Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors."

This audit will focus on the DNB failure census at HFP conditions to ensure that assumptions used in the radiological evaluation in Section 15.0.3 of Reference 1 are bounded by the number of failed fuel rods calculated by MHI's REA evaluation model.

Regulatory Audit Scope:

The regulatory audit will focus on the areas listed below:

1. Short Term Analysis

    - Input assumptions
    - Conservatisms
    - Translation of information from kinetics code TWINKLE-M to core subchannel thermal-hydraulics code VIPRE-01M

2. Long Term Analysis (Fast Depressurization)

    - Input assumptions
    - Conservatisms
    - MARVEL-M outputs showing approximate thermal-hydraulic conditions and timing of low pressurizer pressure trip

3. Long Term Analysis (Slow Depressurization)

    - Basis for Overtemperature Delta T setpoints
    - Verification that thermal-hydraulic and power distributions in post-rod ejection environment is within envelope defined by Overtemperature Delta T trip function. Existing MARVEL-M calculations for the slow depressurization can be used to support crediting the Overtemperature Delta T trip function.

Information and Other Material Necessary for the Regulatory Audit:

The NRC staff requests access to the translated documentation of calculations and design records supporting the response to RAI REA-12 (Reference 4). Also, the NRC staff would like to see a draft reload safety evaluation checklist and draft COLR to ensure that design commitments resulting from the response to REA-12 are incorporated.

Team Assignments:

Jeffery Schmidt (NRC) - Lead Auditor
Andrew Bielen (NRC) - Team Member
Michael Takacs (NRC) - Project Manager
Ruth Reyes (NRC) - Project Manager

Logistics:

The audit is planned for August 4 - 5, 2011, at the Mitsubishi Nuclear Energy Systems office located in Arlington, Virginia.

Special Requests:

The NRC staff requests that MHI provide the requested information, workspace for the NRC staff to review the documents, and a telephone for contacting NRC headquarter staff (if necessary) as coordinated through the project manager.

The NRC staff shall appropriately handle and protect proprietary information throughout the audit.

Deliverables:

Within 45 days of the closing meeting, the NRC staff will generate an audit summary report. The report will describe the outcome of the audit and summarize any open items resulting from the audit, including potential RAIs.

References:

1. US-APWR DCD Revision 3.

2. Mitsubishi Heavy Industries, Ltd., MUAP-07010-P Revision 1, “Non-LOCA Methodology,” dated October 15, 2010.

3. AREVA NP, Inc., ANP-10286P, “US EPR Rod Ejection Accident Methodology Topical Report,” dated November 2007.

4. E-mail from Michael Takacs, NRC, to MHI, “RAI (tenth set) for NonLOCA Topical Report MUAP-07010 – rod ejection analysis,” dated March 8, 2011 (ML110680348).

5. E-mail from Michael Takacs, NRC, to MHI, “RAI (eleventh set) for NonLOCA Topical Report MUAP-07010 - rod ejection analysis,” dated April 8, 2011 (ML111020415).

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