REQUEST FOR ADDITIONAL INFORMATION TOPICAL REPORT
THERMAL DESIGN METHODOLOGY
MUAP-07009 REV. 0

08/20/09

US-APWR TOPICAL REPORT

Mitsubishi Heavy Industries

Docket No. 52-021

STATEMENT OF STAFF REVIEW

In the Topical Report (TR) MUAP-07009-P (Reference 1), Mitsubishi Heavy Industries, Ltd. (MHI) stated that:

"The objective of this topical report is to present a comprehensive thermal design methodology utilized by Mitsubishi Heavy Industries, Ltd. for analyzing the thermal-hydraulic conditions in the MHI-designed Pressurized Water Reactor cores."

MHI then presented a description of VIPRE-01M as well as analyses such that the NRC could make a determination on the acceptability of VIPRE-01M for performing thermal-hydraulic analysis on PWRs. This was submitted to the NRC in accordance with the intent of the Safety Evaluation (SE) on EPRI's VIPRE-01 computer code (Reference 2), specifically conclusion #3 from the SE:

"Each organization using VIPRE-01 for licensing calculations should submit separate documentation describing how they intend to use VIPRE-01 and providing justification for their specific modeling assumptions, choice of particular two-phase flow models and correlations, heat transfer correlations, CHF correlation and DNBR limit, input values of plant specific data such as turbulent mixing coefficient, slip ratio, grid loss coefficient, etc., including defaults."

The NRC has reviewed and approved other such submittals in which organization provided justification for use of VIPRE-01 to perform PWR licensing calculations (References 3, 4, and 5). However, there are differences in scope between those submittals and the current MHI submittal. The previous submittals were used to change a portion of an approved evaluation model (namely, to use VIPRE-01 in place of a different code). The goal of the current MHI submittal is not simply to change one part of an approved evaluation model, but to establish an evaluation model (which would include VIPRE-01M). Therefore, the staff has to verify the justification, not only of the adequacy of VIPRE-01M, but of the entire evaluation model MHI will use to analyze the thermal-hydraulic conditions in the MHI-designed Pressurized Water Reactor cores.

The staff's review is being performed in accordance with SRP15.0.2 (Reference 6) and the corresponding industry guidance is set forth in Regulatory Guide 1.203 (Reference 7).

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REQUESTS FOR ADDITIONAL INFORMATION (RAIs)

Note: accident/transient scenarios include the time dependent portion of the accident or transients as well as the initial steady state calculations.

1.0 Requests for Additional Information on the Evaluation Model

1.1 Identify the specific accident/transient scenarios and plant configurations for each application in which VIPRE-01M will be used.[1] Include the parameters of interest, figures of merit, and limiting transients.

1.2 For the scenarios identified in RAI 1.1 (above), provide justification that the specific accident/transient scenarios can be adequately modeled with VIPRE-01M. This means that models must be present in the VIPRE-01M code to capture the phenomena and components that have been determined to be important or necessary to simulate the accident/transient under consideration. The chosen mathematical models and numerical solution of those models must be able to predict the important physical phenomena reasonably well from both qualitative and quantitative points of view.[1]

1.3 Provide the following listed in Chapter 9.0 of MUAP-07009-P to the NRC: References 1,2,3,4,5, and 18.[1]

1.4 Provide an overview of the thermal design methodology which provides a clear roadmap describing all parts of the thermal design methodology and the relationships between the separate parts.[1]

In this overview, describe where VIPRE-01M receives its inputs, which codes interact with VIPRE-01M (provides input to VIPRE-01M or receives output from VIPRE-01M), and what is done with the output from VIPRE-01M. References should be supplied for any interacting codes, as well as verification that the codes are approved by the NRC and are being used within their conditions and limitations.

1.5 Identify which MOD of VIPRE-01 was used to create VIPRE-01M and which revision of documentation was used. If something other than MOD-01 or MOD-02 were used (for example, MOD-2.1) MHI may need to provide additional justification because even a “small” change to the evaluation model can have unintended consequences on calculation results that were through to not be impacted by the changes.[1]

1.6 The NRC generic safety evaluation report for VIPRE-01 MOD-01 includes five conditions for use of the code. The NRC generic safety evaluation report for VIPRE-01 MOD-02 includes four additional conditions for use of the code. Explicitly state the SE conditions and discuss how MHI will meet each of these conditions using VIPRE-01M.

[1] Reference 6

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1.7 MHI should provide an assessment of the differences between Pressurized Water Reactors which the NRC staff reviewers are accustomed to dealing with and which the VIPRE-01 computer code was licensed for, and MHI-designed Pressurized Water Reactors. MHI should provide justification as the applicability of VIPRE-01 (and subsequently VIPRE-01M) to MHI-designed Pressurized Water Reactors.

1.8 Provide a discussion on rod bow. Include how rod bow will be accounted for (especially in any thermal limits) and the basis for that decision.

1.9 Provide a discussion on transition cores. Include how the transition cores will be accounted for (especially in any thermal limits) and the basis for that decision.

1.10 Provide a discussion and data or analysis on the selection of the constant ABETA, specifically, what is the physical justification for the constant's value?

1.11 Provide a discussion and data or analysis on the selection of the form loss coefficients for grid spacers specifically, verify that the form loss coefficient is applicable to the fuel assembly which will be put in the MHI-designed Pressurized Water Reactors.

1.12 Which radial noding scheme will be used to perform licensing analysis on MHI-designed Pressurized Water Reactors?

1.13 Provide a discussion on the mode which will be used in VIPRE-01M (UPFLOW or RECIRC). Discuss any associated limitations, and why they will be consistent with the accident/transient scenarios modeled with VIPRE-01M in MHI-designed Pressurized Water Reactors. Specifically which input conditions are needed and where the input conditions will be obtained from.

1.14 What values of the core inlet distribution factors will be used to perform licensing analysis on MHI-designed Pressurized Water Reactors?

1.15 How many radial nodes are used in the clad for both steady state and transient applications? Why was this number chosen.

1.16 Provide a further description for the phrase 'initial pellet heat up'.

1.17 Describe the axial nodalization for transient analyses.

1.18 Confirm that the thermal properties for the fuel have been previously reviewed and approved the NRC.

1.19 Provide a discussion identifying each accident/transient scenario and how the gap conductance will be conservative for each of the scenarios modeled with VIPRE-01M.

1.20 Provide a discussion of how the VIPRE-01M implementation of the Zr-Water model is derived from the formulas in the source documents. Include the original continuous equations, the discrete approximation to these, the VIPRE-01M variables, the units of all physical quantities, and the energy released by the

reaction. Step-by-step descriptions and all the equations must be presented in sufficient detail for replication by independent reviewers.

1.21 What fraction of power is deposited directly in the coolant? What fraction of power is deposited directly in the clad? Provide an adequate justification for each.

1.22 Section 6.5 of MUAP-07009-P discusses a correlation that is used to calculate film boiling heat transfer. This correlation was accepted by NRC staff for use in the FRACTRAN code. Provide a list of transients and accidents for which MHI will use VIPRE-01M in the post CHF heat transfer region and discuss the licensing requirement that the calculation is designed to meet. As stated in the NRC generic SE for VIPRE-01, "Post CHF analysis aspects of the code dealing with post-CHF phenomena were excluded from this review," the use of VIPRE for this type of analysis will therefore require additional justification. Please provide justification that VIPRE can conservatively model the mechanical, physical and chemical changes that might occur in the fuel rods at elevated temperature including comparisons with applicable reactor fuel rod test data.

2.0 Requests for Additional Information on the Accident Scenario Identification Process

2.1 Provide a complete description of the accident/transient scenarios which will be analyzed by VIPRE-01M including plant initial conditions, the initiating event and all subsequent events and phases of the accident, and the important physical phenomena and systems and/or component interactions that influence the outcome of the accident.[1]

3.0 Requests for Additional Information on the Code Assessment

3.1 Provide a code assessment of VIPRE-01M. Assessments performed with other versions of VIPRE-01M (such as EPRI's VIPRE-01) require additional justification because even a "small" change to the evaluation model can have unintended consequences on calculation results that were thought to not be impacted by the changes.[1]

3.2 Along with the code assessment of VIPRE-01M, MHI will need to provide an assessment of correct implementation of the code. Comparisons of VIPRE-01M by MHI to other NRC approved codes provide some assessment of the difference between codes, but such a comparison can not provide adequate regulatory basis to justify the evaluation model which VIPRE-01M is a part. Two possible ways to provide adequate regulatory basis for the evaluation model are VIPRE-01M comparisons to data or VIPRE-01M comparisons to analysis performed by an organization with an approved evaluation model. Such analysis should be performed to verify that VIPRE-01M accurately captures the physical phenomena of the accidents/transients of interest for MHI-designed Pressurized Water Reactors.

[1] Reference 6

3.3 Confirm that the code assessment (both the assessment already submitted and any additional assessment) was performed with a frozen version of the evaluation model that has been submitted for review?[1]

3.4 Provide verification and documentation that as a result of the Accident Scenario Identification Process, no new accident/transient scenarios were identified that contain a physical phenomenon that was previously unimportant in the VIPRE-01 code assessment. If a new accident/transient scenario was identified, provide appropriate justification (for example, comparison to separate effects test data) for VIPRE-01M's modeling of that particular physical phenomenon.

3.5 Provide verification and documentation that as a result of the Accident Scenario Identification Process no new accident/transient scenarios were identified that that were not previously identified in the VIPRE-01 code assessment. If a new accident/transient scenario was identified, provide appropriate justification (for example, comparison to integral effects test data) for VIPRE-01M's modeling of that particular accident/transient scenario.

3.6 Provide verification and documentation that as a result of the Accident Scenario Identification Process no new accident/transient scenarios were identified which exceed the parameter range of previously identified accident/transient scenarios in VIPRE-01. If a new accident/transient scenario was identified, confirm that VIPRE-01's models can adequately model the physical phenomena in the new range.

3.7 Confirm that the code options used in the code assessment calculations will be the same as those used in plant accident calculations.[1]

3.8 If scaling was performed, provide a scaling analysis which identifies important non-dimensional parameters related to geometry and key phenomena.[1]

3.9 Confirm and provide documentation that each empirical correlation in VIPRE-01M will be used within its intended range. For the empirical correlations in VIPRE-01M provide a list of those correlations and their ranges.

3.10 For codes which interact with VIPRE-01M, where applicable, provide the results of a null transient. Include comparison of the parameters of interest between the interacting codes.

4.0 Requests for Additional Information on the Uncertainty Analysis

4.1 Provide a sample uncertainty analysis evaluation for a typical plant application.[1] This analysis should include discussion of all the engineering factors used as well as justification for their values. Include in this discussion any assumptions made about the engineering factors (such as the heat flux engineering factor) and provide appropriate justification for those assumptions.

[1] Reference 6

4.2 Discuss how MHI will implement the RTDP analysis, specifically addresses the uncertainties used and the basis for the uncertainties.

5.0 Requests for Additional Information on the Theory Manual

5.1 For VIPRE-01M, provide a theory manual that is a self-contained document and that describes (a) field equations, (b) closure relationships, (c) numerical solution techniques, (d) simplifications and approximations (including limitations) inherent in the chosen field equations and numerical methods, (e) pedigree or origin of closure relationships used in the code, and (f) limits of applicability for all models in the code.[1]

6.0 Requests for Additional Information on the User Manual

6.1 For VIPRE-01M, provide a user manual that provides (a) detailed instructions about how the computer code is used, (b) a description of how to choose model input parameters and appropriate code options, (c) guidance about code limitation and options that should be avoided for particular accidents, components, or reactor types, and (d) if multiple computer codes are used, documented procedures for ensuring complete and accurate transfer of information between different elements of the evaluation model.[1]

6.2 Provide the NRC with a VIPRE-01M executable (preferably PC) and the appropriate input parameters for Runs 1 – 7 on Table 7-1 of the TR such that the NRC may generate their own input deck according to the VIPRE-01M user manual, execute the code, and compare the results to results generated by MHI.

7.0 Requests for Additional Information on the Quality Assurance Program

7.1 Provide the quality assurance plan for VIPRE-01M which describes the procedures and controls under which the code was developed and assessed, and the corrective action procedures that are followed when an error is discovered.[1]

7.2 Verify that the quality assurance plan described in response to RAI 7.1 was used when performing all changes which were required to generate VIPRE-01M from VIPRE-01 and performing all analysis submitted to the NRC. Verify that all VIPRE-01M analyses were performed with a specific frozen version of the code.

[1] Reference 6

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REFERENCES

1. MAUP-07009-P, Rev. 0, "Thermal Design Methodology", May 25, 2007 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML071520271 / ML071520270 (Non-Publically Available / Publically Available)).

2. C.W. Stewart, er al., "VIPRE-01: A Thermal-Hydraulic Code for Reactor Cores," EPRI-NP-2511=CCM, Rev. 4, Vol. 1-5, Battelle Pacific Northwest Laboratories, February 2001

3. WCAP-14565-P-A, "VIPRE-01 Modeling and Qualification for Pressurized Water Reactor Non-LOCA Thermal-Hydraulic Safety Analysis", October 1999 (ADAMS Accession No. ML993160153 / ML993160096 (Non-Publically Available / Publically Available)).

4. DPC-NE-2003P-A Rev.1, "Duke Power Company Oconee Nuclear Station Core Thermal-Hydraulics Using VIPRE-01", June 2000 (ADAMS Accession No. ML003752843 / ML003752817 (Non-Publically Available / Publically Available)).

5. DOM-NAF-2, Rev. 0.0-A, "Reactor Core Thermal-Hydraulics Using the VIPRE-D Computer Code", September 2006 (ADAMS Accession No. ML062650184 (Publically Available)).

6. SRP 15.0.2 "Review of Transient and Accident Analysis Methods", NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," June 1987. (Certain updated sections are available from the NRC.)[1]

7. USNRC, "Transient and Accident Analysis Methods," Regulatory Guide 1.203, December 2005.[2]

[1] Copies are available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4205, by fax at (301) 415-3548, and by email to PDR@nrc.gov. The SRP is also available through the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0800/.

[2] Single copies of regulatory guides, both active and draft, and draft NUREG documents may be obtained free of charge by writing the Reproduction and Distribution Services Section, OCIO, USNRC, Washington, DC 20555-0001, or by fax to (301)415-2289, or by email to DISTRIBUTION@nrc.gov. Copies of certain guides and many other NRC documents are available electronically through NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/. Documents are also available through the NRC's Agencywide Documents Access and Management System (ADAMS), at http://www.nrc.gov/reading-rm/adams.html.