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

November 12, 2008

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-08245

Subject: MHI's 3rd Response to NRC's Requests for Additional Information on US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P

Mitsubishi Heavy Industries, Ltd. ("MHI") transmits to the U.S. Nuclear Regulatory Commission ("NRC") the documents entitled "MHI's 3rd Response to NRC's Requests for Additional Information on US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P" and "MARVEL-M Code Manual, Revision 5." The enclosed materials provide MHI's responses to the NRC's "Requests for Additional Information (RAIs) US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P," dated October 20, 2008. MHI has previously responded to RAIs on the Non-LOCA Topical Report in MHI letters UAP-HF-08141, dated August 22, 2008 and UAP-HF-08170, dated September 12, 2008. The enclosed materials also include the latest revision, Revision 5, of the MARVEL-M code manual. Revision 3 of the MARVEL-M manual was previously submitted by MHI letter UAP-HF-08138, dated August 1, 2008. The latest revision of the MARVEL-M manual is being submitted by MHI because it has editorial corrections that pertain to the RAI responses.

As indicated in the enclosed materials, these documents contain 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 one of the documents is also being submitted in this package (Enclosure 3). In the non-proprietary version, the proprietary information, bracketed in the proprietary version, is replaced by the designation "[ ]".

This letter includes a copy of the proprietary version of the RAI response (Enclosure 2), a copy of the non-proprietary version of the RAI response (Enclosure 3), the latest revision of the MARVEL-M code manual (Enclosure 4), and the Affidavit of Yoshiki Ogata (Enclosure 1) which identifies the reasons MHI respectfully requests that all material designated as "Proprietary" in Enclosures 2 and 4 be withheld from disclosure pursuant to 10 C.F.R. § 2.390 (a)(4).

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.

D081
NRO

Enclosures:

1. Affidavit of Yoshiki Ogata
2. MHI's 3rd Response to NRC's Requests for Additional Information on US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P (proprietary)
3. MHI's 3rd Response to NRC's Requests for Additional Information on US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P (non-proprietary)
4. MARVEL-M Code Manual, Revision 5 (proprietary)

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: ckpaulson@mnes.com
Telephone: (412) 373-6466

ENCLOSURE 1

Docket No. 52-021

MHI Ref: UAP-HF-08245

MITSUBISHI HEAVY INDUSTRIES, LTD.

AFFIDAVIT

I, Yoshiki Ogata, being duly sworn according to law, depose and state as follows:

1. I am General Manager, APWR Promoting Department, of Mitsubishi Heavy Industries, Ltd. ("MHI"), and have been delegated the function of reviewing MHI's 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 documents entitled "MHI's 3rd Response to NRC's Requests for Additional Information on US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P" and "MARVEL-M Code Manual, Revision 5," both dated November 2008, and have determined that the documents 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 documents 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 basis for holding the referenced information confidential is that it describes the unique design of the safety analysis, developed by MHI (the "MHI Information").

4. The MHI Information is 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. Therefore public disclosure of the materials would adversely affect MHI's competitive position.

5. The referenced information has in the past been, and will continue to be, held in confidence by MHI and is always subject to suitable measures to protect it from unauthorized use or disclosure.

6. The referenced information is not available in public sources and could not be gathered readily from other publicly available information.

7. The referenced information is being furnished to the Nuclear Regulatory Commission ("NRC") in confidence and solely for the purpose of supporting the NRC staff's review of MHI's application for certification of its US-APWR Standard Plant Design.

8. Public disclosure of the referenced information would assist competitors of MHI in their design of new nuclear power plants without the costs or risks associated with the design and testing of new systems and components. Disclosure of the information identified as

proprietary would therefore have negative impacts on the competitive position of MHI in the U.S. nuclear plant market.

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 12nd day of November, 2008.

Y. Ogata

Yoshiki Ogata

Enclosure 3

UAP-HF-08245
Docket No. 52-021

November 2008

MHI's 3rd Response to NRC's Requests for Additional Information on US-APWR Topical Report: Non-LOCA Methodology, MUAP-07010-P

(Non-Proprietary)

RAI 2.1-21
As shown in the figure on page 2-3 of MUAP-07010-P, MHI did not begin development of MARVEL-M starting with the approved version of MARVEL, but rather an earlier version. Detail the differences between MARVEL-M and the approved version of MARVEL.

Response

History of MARVEL-M

The historical development of the MARVEL-M code is shown in Figure 2.1-21.1 below. It is an updated version of the figure from page 2-3 of the Non-LOCA Methodology Topical Report (MUAP-07010-P) which provides additional information and corrects the LOFTRAN WCAP number and date.

Figure 2.1-21.1 Historical Development of the MARVEL-M Code

In addition to these features, MHI made some improvements and refinements to the MARVEL code independently of Westinghouse. These modifications were described in the Non-LOCA

Methodology Topical Report, MUAP-07010-P, submitted to the NRC in July of 2007. The resultant code was designated MARVEL-M and is described in the MARVEL-M manual (GEN0-LP-480). The latest revision of the MARVEL-M manual, Revision 5, is being submitted to the NRC for approval concurrent with this RAI response as Enclosure 4 to MHI letter UAP-HF-08245.

The purpose of the response to this RAI is to compare the previously approved version of MARVEL to MARVEL-M. The comparison between the approved version and MARVEL-M is divided into two separate discussions: (1) features that are available in the approved version that were not in the original MHI version of MARVEL in 1972 and (2) new features that were added to the code by MHI during the creation of MARVEL-M. All of the features from case (1) and (2) are shown in Table 2.1-21.1. Each of the differences in Table 2.1-21.1 will also be described here in detail.

Given the description of the differences between the approved version of MARVEL and MARVEL-M, the parts of MARVEL-M that need to be reviewed for NRC approval and the parts that can be considered as having been previously reviewed and approved by the NRC can be determined.

Proprietary vs. Non-Proprietary Versions of Approved MARVEL

Comparison between Approved Version and MARVEL (1972)

There are eight features described below in the NRC approved version of MARVEL that were not included in the original version of MARVEL in 1972.

For the first six features, MHI independently added equivalent models of these features to the MHI version of MARVEL, currently designated MARVEL-M. These features are mainly used for the steamline break mass and energy release in the US-APWR DCD Chapter 6 analyses.

The last two features that were in the approved version of MARVEL but not the original MHI version of MARVEL have not been incorporated into the MHI version of MARVEL because these features are not needed for the non-LOCA safety analyses in Japanese domestic plants or the US-APWR design.

Comparison between MARVEL (1972) and MARVEL-M (MUAP-07010-P)

The previous discussion focused on features available in the approved version of MARVEL that were not included in the original version of MARVEL in 1972. As mentioned before, there are also features that have been added to MARVEL-M that do not exist in the approved version of MARVEL. These features are described in the Non-LOCA Topical Report, MUAP-07010, in the MHI RAI responses on that topical report, and in the latest revision of the MARVEL-M manual (Revision 5). The new MARVEL-M features are listed here, along with the corresponding references to sections in the topical report, responses to RAIs, or the MARVEL-M manual. MHI expects these models (listed below) to be the focus of the NRC review of the MARVEL-M code for use in analyzing the US-APWR. Major modifications are described in numbers 9 through 12 and other refinements are described in numbers 13 through 18.

9) *4-Loop Reactor Coolant System Model*: The approved version of MARVEL uses a 2-loop reactor coolant system (RCS) model. MHI has modified MARVEL-M to have a 4-loop RCS model. The details of the 4-loop RCS model are found in Section 2.1.3.1 of the Non-LOCA Methodology Topical Report, Section 1.3 of the MARVEL-M manual, and the response to RAI 2.1-1.
10) *Flow Mixing in the Reactor Vessel for a 4-Loop Model*: The approved version of MARVEL uses a 2-loop mixing model. MHI has modified MARVEL-M to have a 4-loop mixing model. The details of the 4-loop mixing model are found in Section 2.1.3.2 of the Non-LOCA Methodology Topical Report, Section 1.4 of the MARVEL-M manual, and the response to RAIs 2.1-5, 2.1-11, 2.1-12, 2.1-13, 2.1-14, and 2.1-15.
11) *Explicit Reactor Coolant Pump Model*: The approved version of MARVEL uses a simplified empirical flow coastdown model and a transition from this flow model to natural circulation. MHI has modified MARVEL-M to use an explicit reactor coolant pump (RCP) model. The details of the explicit RCP model are found in Section 2.1.3.3 of the Non-LOCA Methodology Topical Report, Section 1.7 of the MARVEL-M manual, and the responses to RAIs 2.1-6, 2.1-7, 2.1-16, 2.1-17, and 2.1-18.
12) *Secondary Steam System for a 4-Loop Model*: The approved version of MARVEL uses a 2-loop secondary steam system model. MHI has modified MARVEL-M to have a 4-loop steam system model. The details of the 4-loop steam system model are described in Section 2.1.3.4 of the Non-LOCA Methodology Topical Report and Section 1.8 of the MARVEL-M manual.
13) *Pressurizer Surge Line Model*: MHI has modified MARVEL-M to include a pressurizer surge line model. The details of the pressurizer surge line model are found in Section 2.1.3.5 of the Non-LOCA Methodology Topical Report. The surge line node is shown in Table 2.1-1 and Figure 2.1-3.
14) *Hot-spot Fuel Thermal Kinetics Model*: MHI has modified MARVEL-M to include a hot-spot fuel thermal kinetics model. The details of the hot-spot fuel thermal kinetics model are found in Section 2.1.3.5 of the Non-LOCA Methodology Topical Report and Section 1.2.3 of the MARVEL-M manual.
15) *Core Void Simulation*: MHI has modified MARVEL-M to include a core void simulation model. The details of the core void simulation model are found in Section 2.1.3.5 of the Non-LOCA Methodology Topical Report and Section 4.0 of the MARVEL-M manual.
16) *Feedline Break Blowdown Simulation*: MHI has modified MARVEL-M to include a feedline break blowdown simulation model. The details of the feedline break blowdown simulation model are found in Section 2.1.3.5 of the Non-LOCA Methodology Topical Report and further discussed in Section 5.5. It is also discussed in Section 1.5.5 of the MARVEL-M manual and the feedline break simulation parameters are described in Section 2.8 of Part II.
17) *Conversion of RCS Volume Balance by Pressure Search*: MHI has modified MARVEL-M to include conversion of RCS volume balance by pressure search. The details of this model are found in Section 2.1.3.5 of the Non-LOCA Methodology Topical Report. It is also discussed in Section 4.0 of the MARVEL-M manual and the input parameters are given in Section 2.13.2 of Part II.
18) *Realistic Models*: MHI has modified MARVEL-M to include the optional ability to model realistic events. The details of the realistic models are found in Section 2.1.4 of the Non-LOCA Methodology Topical Report, Section 3.0 of the MARVEL-M manual, and the response to RAI 2.1-20.

Verification of the Improvements to the MARVEL-M Code

The features numbered 9 through 14 and 17 were verified by comparisons with the NRC approved 4-loop LOFTRAN code from the viewpoint of total RCS behavior, including 4-loop simulation and the built-in RCP model. MARVEL-M and LOFTRAN were compared for the "Uncontrolled RCCA Bank Withdrawal at Power", "Partial Loss of Forced Reactor Coolant Flow", "Complete Loss of Forced Reactor Coolant Flow", and "Reactor Coolant Pump Shaft Seizure" events as described in Section 3.1 of the Non-LOCA Methodology Topical Report, as well as the "Loss of Non-Emergency AC Power to the Station Auxiliaries" event as described in the MHI response to RAI 2.1-17. Confirmation of feature 16 is included in this response by the steamline break comparison with the LOFTRAN code described in the following paragraph. Feature number 15 is only used for transferring data from VIPRE-01M to MARVEL-M in the reactivity initiated events. Feature number 18 is not used in the US-APWR safety analysis although a sample transient analysis of a steam generator tube rupture is shown in Appendix F of the Non-LOCA Methodology Topical Report.

In this response, MHI performed a comparison between MARVEL-M and LOFTRAN to confirm the features numbered 1 through 5 and 16 (the feedline break blowdown uses the Moody correlation, the same as the steamline break flow). Figures 2.1-21.2 through 2.1-21.13 compare relevant parameters associated with the steamline break mass and energy release that is described in US-APWR DCD Chapter 6*. In Figure 2.1-21.12, MARVEL-M overestimates the feedwater flow because MARVEL-M conservatively assumes no pressure drop in the feedwater line during feedwater flashing. Other than the difference in feedwater flow, the results of the two codes agree very well for each parameter of interest in the figures. Therefore MHI concludes that the features numbered 1 through 5 and 16 have been correctly incorporated into the MARVEL-M code.

Conclusion

- MHI's development of MARVEL-M began from an earlier version rather than the NRC approved version of MARVEL.
- There are some differences between the approved version and the original MHI version; the approved version has additional features.
- MHI incorporated equivalent models of these features into MARVEL-M and verified them through comparisons with the 4-loop LOFTRAN code approved by the NRC.
- Therefore, MARVEL-M includes these features of the NRC approved MARVEL version.
- MHI then made additional modifications and improvements to MARVEL-M that are not in the approved version of MARVEL.
- MHI expects the additional modifications described in the Non-LOCA Methodology Topical Report to be the focus of the NRC review of the MARVEL-M code for use in analyzing the US-APWR.

References

1) "Non-LOCA Methodology Topical Report", MUAP-07010-P, dated July 2007.
2) "MHI's Response to NRC's Request for Additional Information on US-APWR Topical Report MUAP-07010-P, Non-LOCA Methodology," MHI Letter UAP-HF-08141, dated August 22, 2008.
3) "MHI's 2nd Response to NRC's Request for Additional Information on US-APWR Topical Report MUAP-07010-P, Non-LOCA Methodology," MHI Letter UAP-HF-08170, dated September 12, 2008.

Table 2.1-21.1 Comparison between Approved Version of MARVEL and MARVEL-M

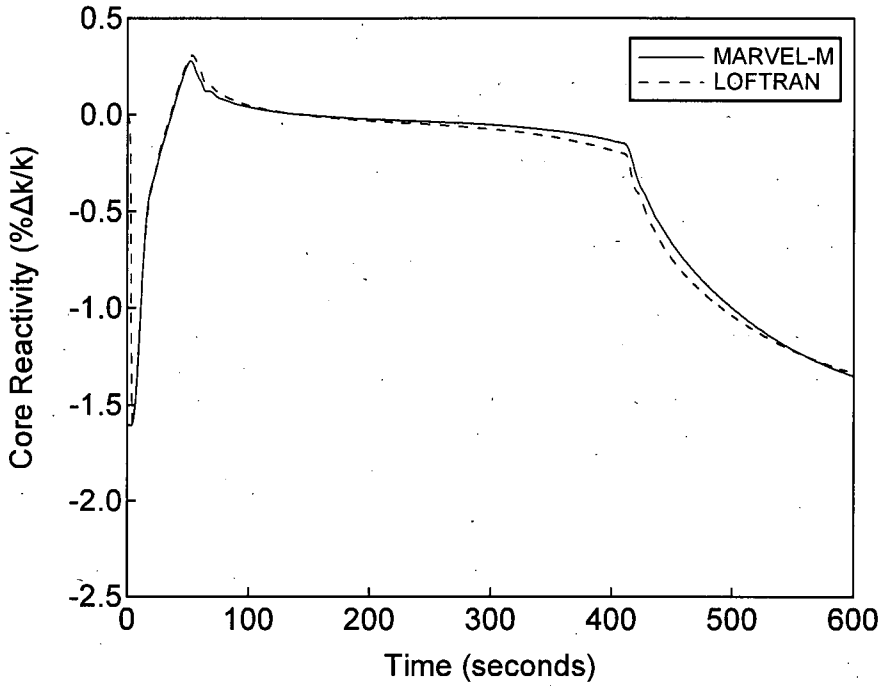

Figure 2.1-21.2 **Core Reactivity versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

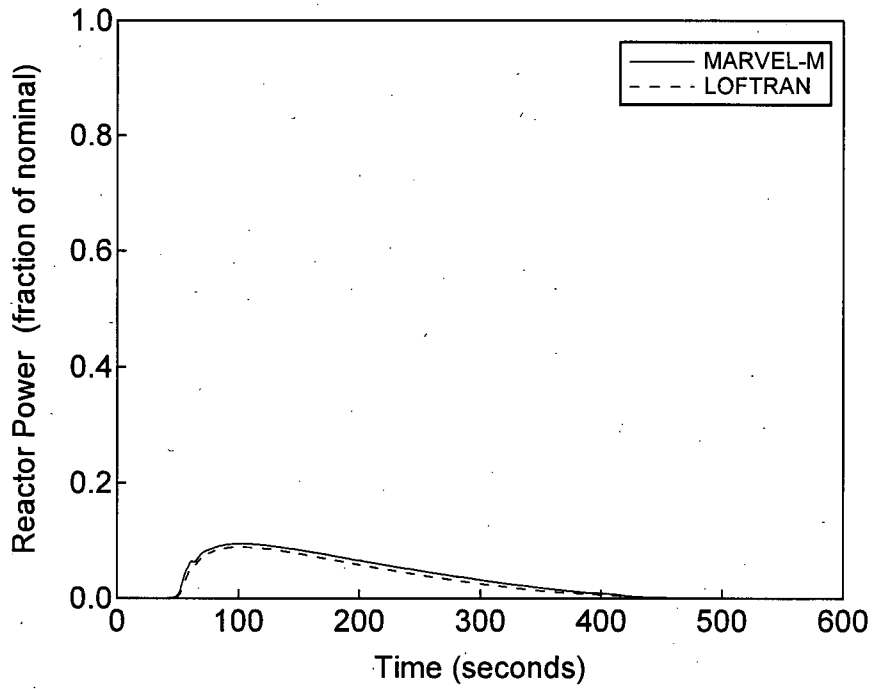

Figure 2.1-21.3 **Reactor Power versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

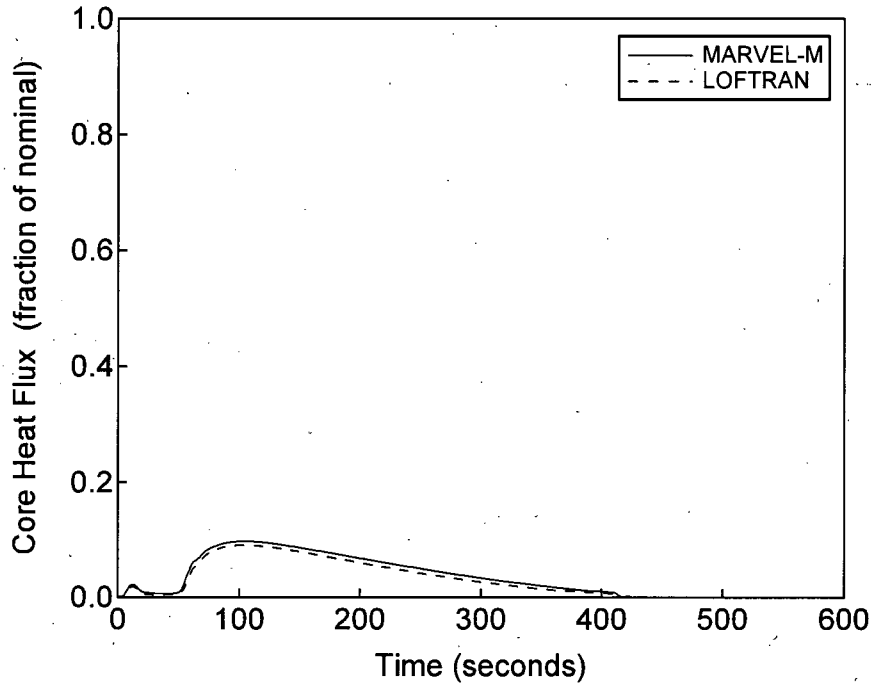

Figure 2.1-21.4 **Core Heat Flux versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

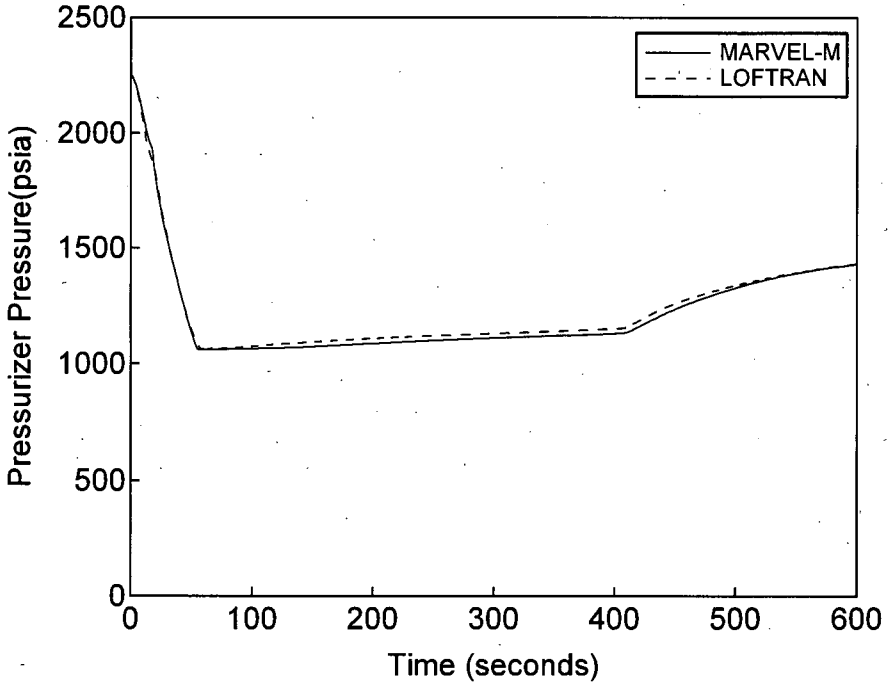

Figure 2.1-21.5 **Pressurizer Pressure versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

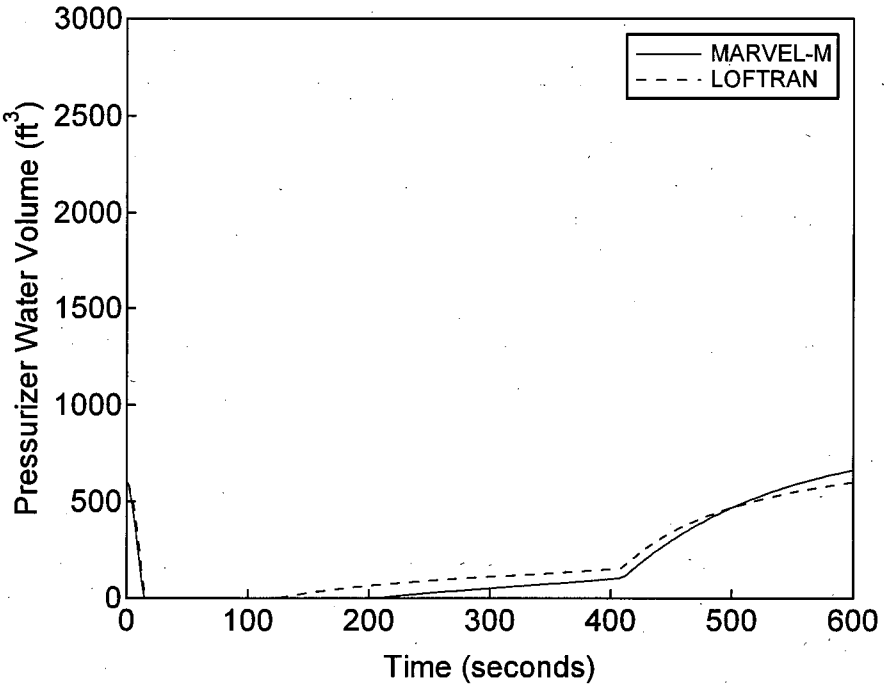

Figure 2.1-21.6 **Pressurizer Water Volume versus Time
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN**

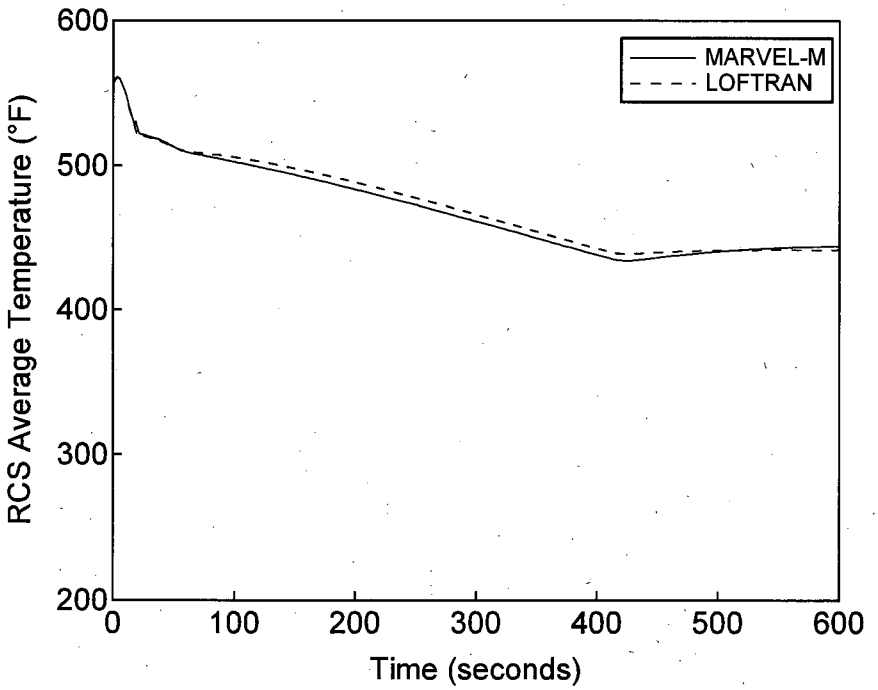

Figure 2.1-21.7 **RCS Average Temperature versus Time
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN**

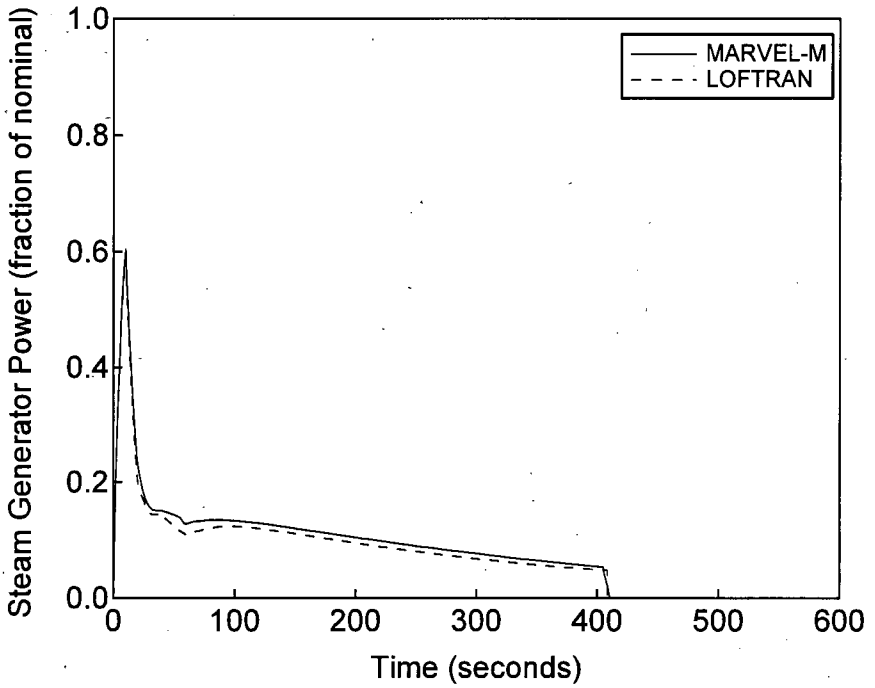

Figure 2.1-21.8 **Steam Generator Power versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

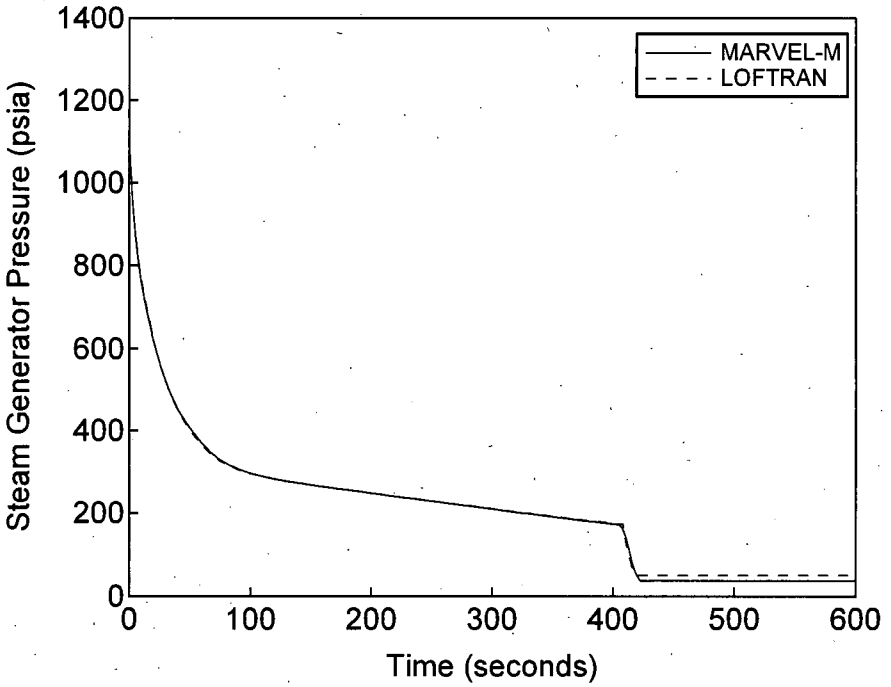

Figure 2.1-21.9 **Steam Generator Pressure of Faulted SG versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

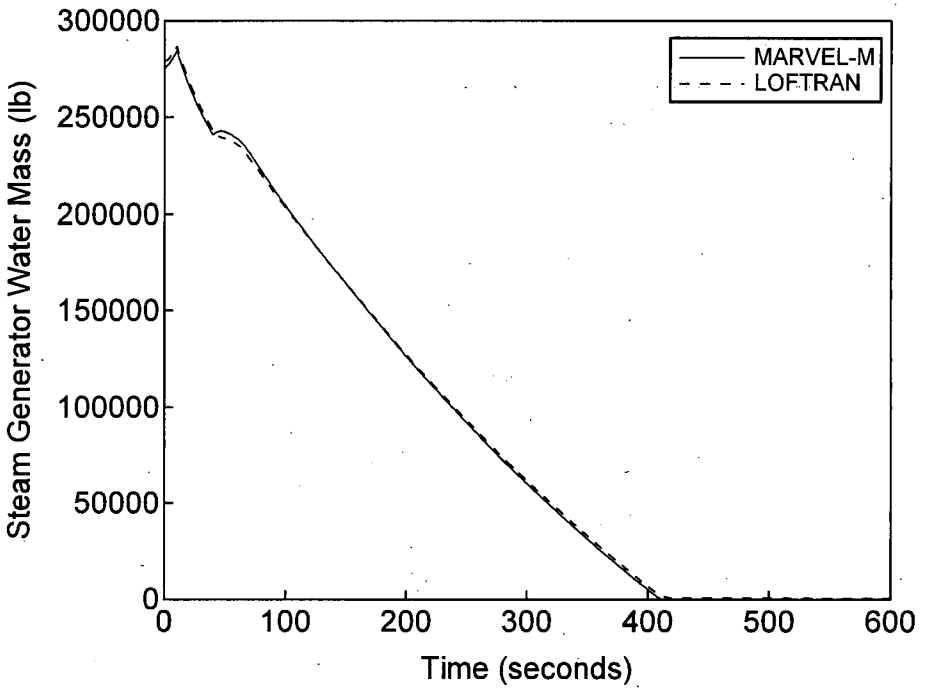

Figure 2.1-21.10 **Steam Generator Water Mass of Faulted SG versus Time Mass and Energy Release for Steam System Piping Ruptures Comparison between MARVEL-M and LOFTRAN**

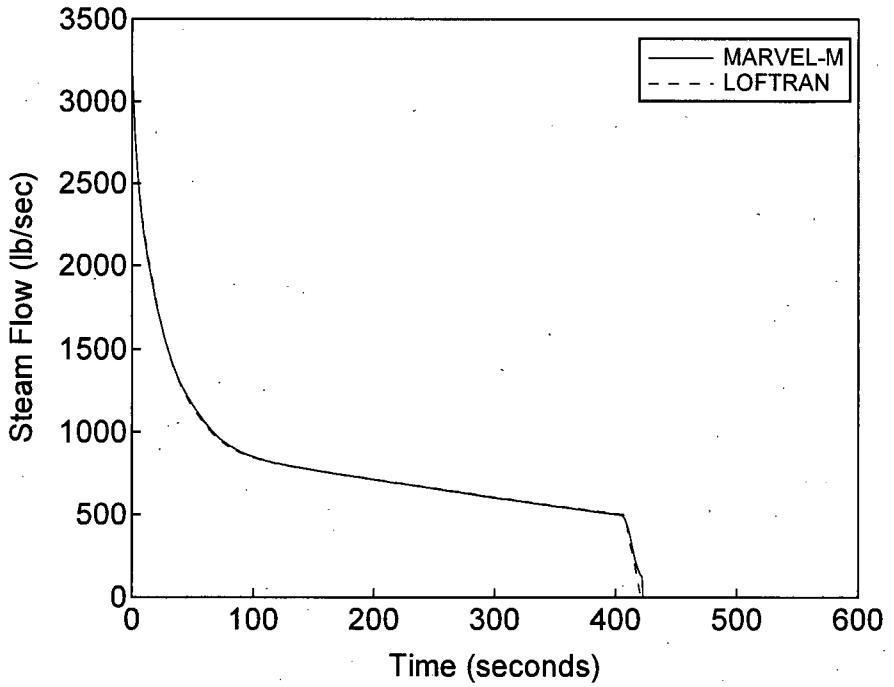

Figure 2.1-21.11 **Steam Flow Rate of Faulted SG versus Time Mass and Energy Release for Steam System Piping Ruptures Comparison between MARVEL-M and LOFTRAN**

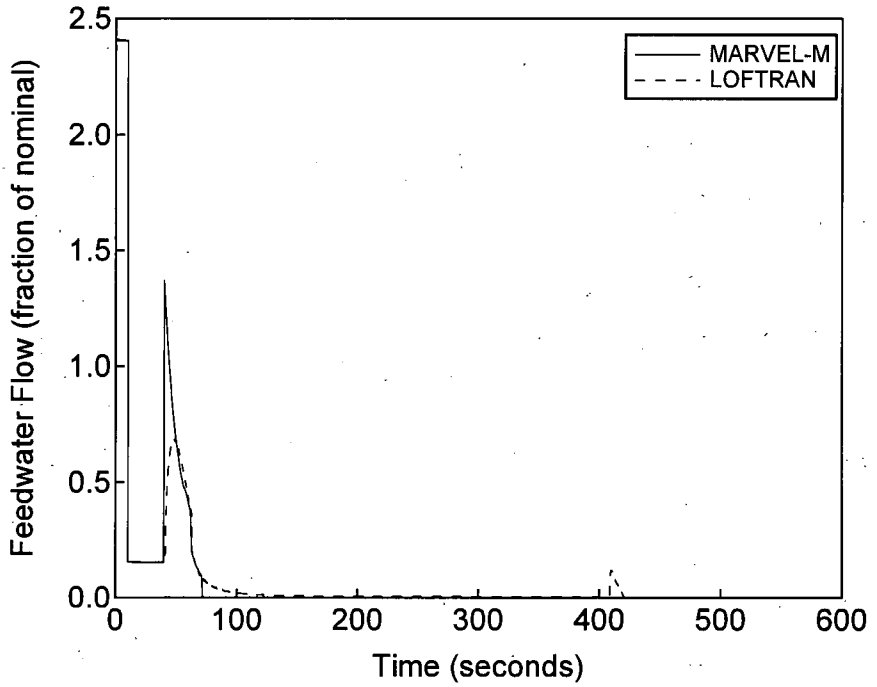

Figure 2.1-21.12 **Feedwater Flow Rate of Faulted SG versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

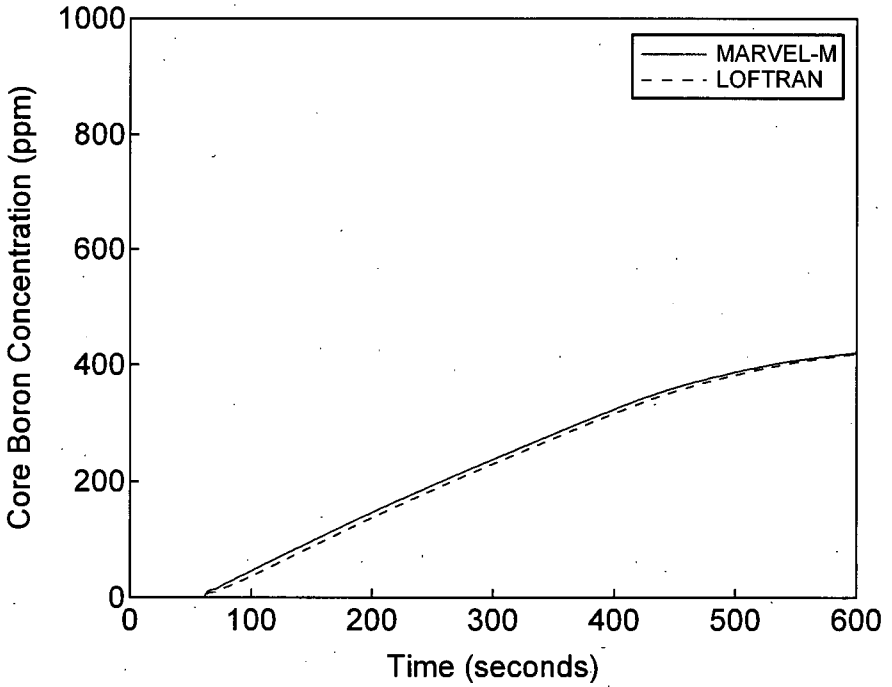

Figure 2.1-21.13 **Core Boron Concentration versus Time**
Mass and Energy Release for Steam System Piping Ruptures
Comparison between MARVEL-M and LOFTRAN

RAI 2.1-22
In accounting for the differences between MARVEL-M and the NRC approved version of MARVEL, are there any limitations beyond those already described in MUAP-07010 which are applicable to the use of MARVEL-M for the US-APWR design?

Response
There are no limitations in MARVEL-M compared to the NRC approved version of MARVEL (WCAP-8843-P/WCAP-8844-NP). The program is designed to be run within the following ranges of operating variables described in Section 2.1.5.1 of Non-LOCA Methodology Topical Report:

- Reactor Coolant System Temperature and Pressure
  Temperature : 50°F to approximately 1100°F
  Pressure : 50 psia to critical pressure (about 3200 psia)
- Pressurizer Water Level
  From empty to full including water discharge. (After the pressurizer is emptied, the program may analyze the system behavior until the coolant in the reactor vessel inactive volume (dead volume) is boiled off.)
- Steam Generator
  Steam Pressure : 14 psia to 1500 psia
  Water Inventory : Empty to moderately high level
- Reactor Coolant Loop Flow
  Forward, reverse and natural circulation flows are computed. Two phase flows are also permitted as a homogeneous equilibrium mixture of vapor and liquid.
- Reactor Core Kinetics
  Reactor power : Neutron source level to overpower level
  Reactivity : Sub-critical to super-prompt critical

The program is intended to cover a very wide range of operating parameters. However, when the plant operating variables deviate excessively from the normal operating conditions, care must be used in interpreting the results in context with the accuracy and limitations of the code models over the regions where the variables are extreme.

RAI 2.1-23
In the NRC evaluation of Westinghouse topical reports WCAP-7909-P and WCAP-8843-P, MARVEL was approved for use to analyze the following four events: steamline rupture, feedwater line rupture, startup of an inactive reactor coolant loop, and excessive heat removal due to a feedwater system malfunction. However, MHI is utilizing MARVEL-M to analyze many events in DCD Chapter 15 beyond these four. Explain why MHI believes this is acceptable.

Response

The disturbances caused by postulated uniform events are milder than those of non-uniform events. Moreover, almost all of the MARVEL models used for the postulated non-uniform events are common to uniform events except for certain specific models related to the initiating events, such as rod withdrawal and primary depressurization.

In order to show that the MARVEL code could be used to analyze other events, MHI made comparisons of MARVEL-M to the NRC approved 4-loop LOFTRAN. The MARVEL-M and 4-loop LOFTRAN comparisons for a variety of uniform and non-uniform events are described in detail in the Non-LOCA Methodology Topical Report, MUAP-07010. Sections 3.1.1 through 3.1.4 compare MARVEL-M to 4-loop LOFTRAN for an uncontrolled RCCA bank withdrawal at power (a uniform event), a partial loss of forced reactor coolant flow (a non-uniform event), a complete loss of forced reactor coolant flow (a uniform event), and a reactor coolant pump (RCP) shaft seizure (a non-uniform event), respectively. Overall, the MARVEL-M results agree very well with the results of the NRC approved 4-loop LOFTRAN code. MHI also supplemented the comparisons for these four events as part of the response to RAIs 3.1-2 through 3.1-5 on the Non-LOCA Methodology Topical Report. The response to RAI 2.1-17 provides a comparison of MARVEL-M and LOFTRAN for a loss of non-emergency AC power to station auxiliaries (a uniform event before auxiliary feedwater initiation and a non-uniform event after auxiliary feedwater initiation). Not only does this provide a comparison for an additional event, it also provides a verification of the ability of the explicit RCP model in MARVEL-M to transition to natural circulation flow.

MHI has also made comparisons of MARVEL-M results to measured data. The response to RAI 2.1-16 shows comparisons of MARVEL-M results to measured data from a 4-loop plant for a partial loss of forced reactor coolant flow and a complete loss of forced reactor coolant flow. These results show that MARVEL-M matches data for both uniform and non-uniform events as well as verifying the explicit RCP model.

In addition to the comparisons of MARVEL-M with LOFTRAN, MHI has also compared MARVEL-M (4-loop) to the original 2-loop MARVEL code from Westinghouse. The response

to RAI 2.1-3 shows the results of the comparisons for a loss of load (a uniform event) and a feedwater system pipe break (a non-uniform event). This comparison was performed as part of the verification of the transition to an explicit 4-loop code.

Despite the fact that the NRC evaluation of MARVEL was focused on four specific (non-uniform) events, MARVEL-M has been shown to provide excellent agreement with the NRC approved version of LOFTRAN, measured plant data, and the original MARVEL for a variety of events. For this reason, MHI believes that it is acceptable to use MARVEL-M for the DCD Chapter 15 accident analyses.

RAI 2.2-2
Elaborate further on the development history of TWINKLE-M. Are there any differences between the TWINKLE version used to develop TWINKLE-M and the NRC approved version described in WCAP-7979-P-A? Include, if possible, a figure describing the development of TWINKLE-M analogous to the figure describing the development of MARVEL-M found on page 2-3 of MUAP-07010-P.

Response

MHI then made modifications to this version of TWINKLE to create TWINKLE-M. The modifications made by MHI have been described in detail in Section 2.2 of the Non-LOCA Methodology Topical Report (MUAP-07010), in the response to RAIs 2.2-1, 3.2-1, and 3.2-2 on the Non-LOCA Methodology Topical Report, and in Section 1 of the TWINKLE-M input manual which was submitted to the NRC on August 1, 2008 by MHI letter UAP-HF-08138. A figure detailing the development of TWINKLE-M is shown below.

Figure 2.2-2.1 Historical Development of the TWINKLE Code

The following description of the differences between the approved version of TWINKLE and TWINKLE-M is taken directly from the response to RAI 2.2-1, which was submitted to the NRC on August 22, 2008 by MHI letter UAP-HP-08141:

The solution methods and constitutive models of the TWINKLE-M code have not changed from the original TWINKLE code. MHI has modified several functions which are mainly concerned with the treatment of input data. A brief description of each change is provided below. GEN0-LP-517 Revision 0 (the TWINKLE-M Input Manual), submitted to the NRC by MHI letter UAP-HF-08138 on August 1, 2008, provides additional information regarding TWINKLE-M input.

(1) Spatial Mesh Expansion
In response to a change in the fuel failure thresholds for reactivity initiated events for Japanese LWRs in 1993, the maximum number of spatial mesh points in the TWINKLE-M code was expanded from 2000 meshes to a variable number in order to support a full core three-dimensional representation. The related variables in TWINKLE-M of fuel burnup, macroscopic and microscopic cross section, xenon distribution, fuel temperature, fast and thermal neutron flux, neutron velocities, and delayed neutron fractions were also expanded to accommodate the full core three-dimensional calculations. The capability to solve three-dimensional problems and solution algorithms were not changed.

(2) Introduction of a Discontinuity Factor
A discontinuity factor was added as a new input process in the program. The purpose of the discontinuity factor is to improve the representation of the local power distribution in the three-dimensional calculations. The addition of the discontinuity factor does not change the diffusion equations in TWINKLE. Instead, the discontinuity factor implementation is shown in Figure 2.2-2.2 and described as follows:

- The macroscopic cross section data is divided by the discontinuity factor before solving the diffusion equations (additional process).
- The neutron flux is solved using the unchanged TWINKLE diffusion equation subroutine.
- The neutron flux is divided by the discontinuity factor to determine the mesh averaged neutron flux (additional process).

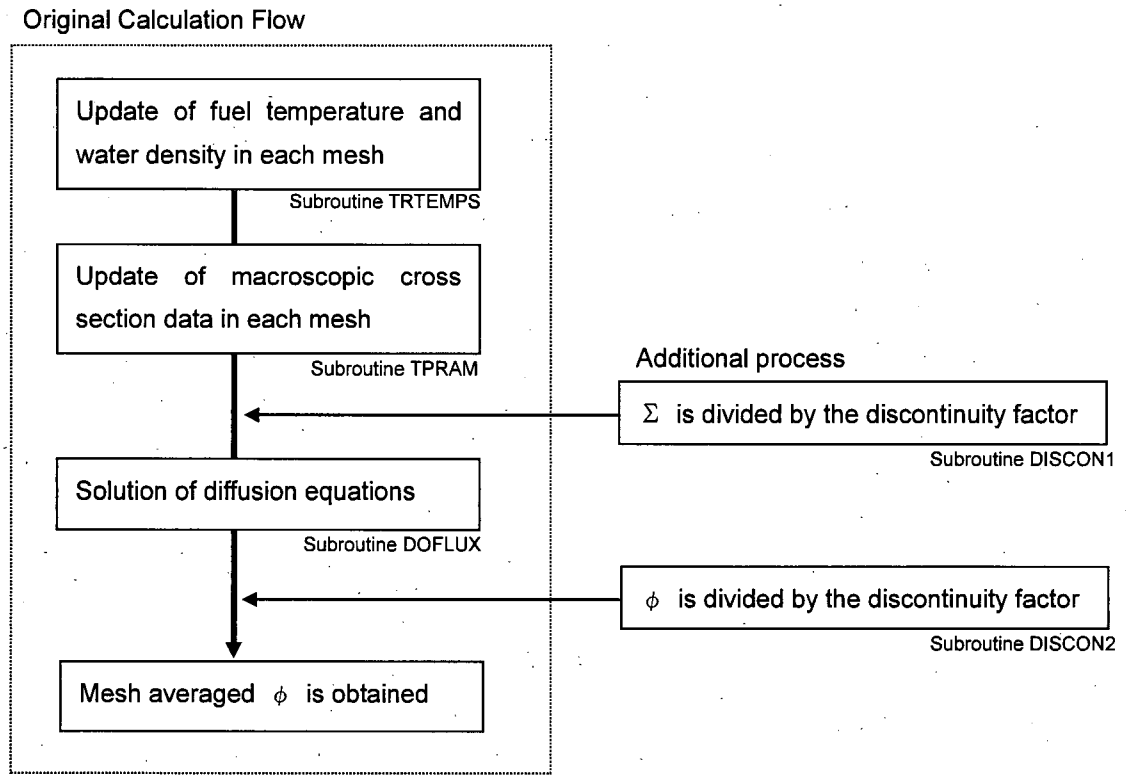

Figure 2.2-2.2 Flowchart of the Discontinuity Factor Process

(3) Input Format
The input format was changed from a numerical identifier form to a Namelist form supported by standard Fortran 77 or 90 compilers. This allows users to identify the input list more clearly.

(4) Additional Options
The following features were added by MHI as input options:

- The nuclear and thermal properties of MOX fuel and BP were included.
- The number of fuel pellet divisions in the radial direction is expanded from 4 meshes to 10 meshes.
- Fuel properties depending on the fuel BU were added such as a thermal conductivity and a radial power depression in the pellet.
- Xenon distribution data calculated by ANC can be passed to TWINKLE-M through an input file. This change provides for a savings in calculation time.
- A separate equation was added to represent the dashpot portion of the trip curve. Prior to this change, the dashpot region was a continuation of the linear portion of the trip curve. The resulting trip curve is now an "S" shaped curve that is more representative of the RCCA displacement curve.
- New outputs were created to aid in the interpretation of code results by allowing for additional data plots and providing the ability to perform sequential calculations with VIPRE-01M. Specific examples of these changes include:
  - Time history of core average power, peaking factor, axial offset, etc.
  - Mesh-wise power distribution map for each time
  - Mesh-wise adiabatic fuel enthalpy rise during a power excursion

Appendix A

Proprietary vs. Non-Proprietary Versions of Approved MARVEL