RETRAN-3D MOD001f DESIGN REVIEW FINAL REPORT

EPRI-RET3-DRFR-001, REVISION 0

DECEMBER 1996

Prepared for

ELECTRIC POWER RESEARCH INSTITUTE

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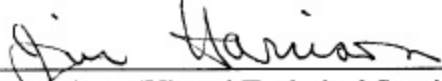
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by the Design Review Committee

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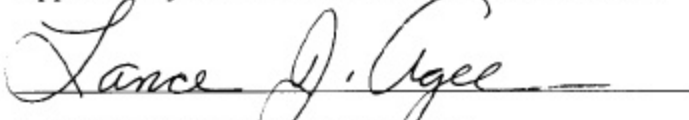
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Prepared for

ELECTRIC POWER RESEARCH INSTITUTE

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12/31/96

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1.0   INTRODUCTION

The Electric Power Research Institute (EPRI) has established a team to perform a design review of the RETRAN-3D MOD001f computer program. A letter included in the Design Review Plan[1-1] from Mr. Lance Agee of EPRI, the project manager for the RETRAN project, forms the basis for initiating the design review. The design review covers verification of the theory and programming, and validation and qualification of the RETRAN-3D MOD001f computer program. The validation and qualification review emphasizes the use of RETRAN-3D MOD001f for some of the transients and abnormal events defined in Chapter 15 of "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants - LWR Edition", NUREG-0800. These events and other application areas of interest to EPRI are provided in the Design Review Plan and listed in Tables 1, 2, and 3 in Appendix A.

The RETRAN-3D MOD001f computer code is the latest version of the RETRAN code series. It has evolved from RETRAN-02 and includes all applicable error corrections through MOD005.2. Additionally, a number of new models and improvements to old models have been implemented to extend the range of analysis capability and improve the accuracy. To the extent deemed consistent with the independent design review concept, the DRC has taken the evolutionary aspects of the RETRAN codes into consideration as a part of our review. Additionally, material from previous design review and quality assurance activities associated with the RETRAN codes was part of the materials used by the present DRC. The resources available to the DRC were used to focus on the new and modified aspects of RETRAN-3D MOD001f.

The Design Review Committee (DRC) consists of individuals who have considerable knowledge in the design, development, and application of large, complex system-wide transient-analysis computer codes such as RETRAN-3D MOD001f.

The DRC members are:

C	Sam Forkner, Signal Mountain Software & Engineering Consultants
C	Jim Harrison, Virtual Technical Services, Inc.
C	Dan Hughes, Hughes and Associates (formerly of Computer Simulation & Analysis, Inc.)
C	John Sorensen, S. Levy, Inc.
C	Marv Thurgood, John Marvin, Inc.

The DRC members represent over 125 years of experience in the nuclear safety analysis industry. The areas of expertise represented on the DRC include: (1) multi-phase thermal sciences, (2) neutron kinetics, (3) development of mathematical models and solution methods, (4) software development, (5) application of large, complex engineering software, (6) analysis of nuclear steam supply systems with engineering software, and (7) understanding of PWR and BWR nuclear steam supply systems and safety analyses of these systems.

The members of the committee have not been a part of the development of the RETRAN-3D MOD001f code nor have they applied the code to analyses of nuclear steam supply systems. Resumes for each of the DRC members are included in the Design Review Plan. The DRC

members are deemed qualified to perform the design review in accordance with the requirements identified in the Design Review Plan.

1.1   References for Section 1.0

1-1   "Design Review Plan for RETRAN-3D MOD001f", EPRI-RET3-DRP-001, Revision 1.

2.0   DESIGN REVIEW OBJECTIVES AND SCOPE

2.1   Design Review Objectives

The objectives of this Design Review of RETRAN-3D are to:

1.   Assure that RETRAN-3D MOD001f satisfies the EPRI criteria for release of computer software. That is, assure that RETRAN-3D MOD001f satisfies the following requirements:

   a.   Adequate documentation must exist which:
      •   describes the theory and assumptions made in developing the models and methods used in the code,
      •   describes the code structure and overall execution procedures,
      •   describes in detail how to use the code, and
      •   describes how to install the code on a user's computer system.

   b.   The code must be verified to assure:
      •   the coding is correct with respect to the code specification document,
      •   the numerical solution methods are stable and convergent, and
      •   the code is correctly solving the equation set programmed.

   c.   The code is validated to perform the analysis in its application areas by one or more of the following:
      •   comparison with relevant experimental and analytical data,
      •   comparison against similar calculation techniques, and
      •   assuring that all results are consistent with physical assumptions made.

2.   Assure that RETRAN-3D MOD001f is qualified to perform analyses of operational transients and abnormal events in its intended application areas. That is:

   a.   Assure that RETRAN-3D MOD001f can be used for analysis for which RETRAN-02 MOD5.1 is currently approved by existing SERs and TERs which state in part, " ...acceptable [for]... Chapter 15 of NUREG-0800 and other transients and events as appropriate and necessary for nuclear power plant operation, but excludes Appendix K LOCA analysis."

b.   Assure that RETRAN-3D MOD001f is capable of performing best-estimate analysis of:
- BWR stability,
- BWR control rod drop,
- PWR control rod ejection,
- PWR steam line break,
- mid-loop operations for PWRs, and
- both full and partial ATWS for both PWRs and BWRs.

2.2   Scope

The design review of RETRAN-3D MOF001f was performed in accordance with the "Design Review Plan for RETRAN-3D MOD001f", EPRI-RET3-DRP-001, Revision 1. The Design Review Plan is a controlled document that conforms to the CSA QA procedures and complies with 10CFR50 Appendix B.

The resources available to the DRC were used to focus on the new and/or modified aspects of RETRAN-3D MOD001f. Additionally, the methods and procedures used for previous successful design reviews conducted on other EPRI software have formed the basis of the present review.

3.0   DESIGN REVIEW SUMMARY

3.1   EPRI Documentation Release Criteria

The DRC has reviewed all pertinent RETRAN-3D documentation. As a result of that review, the DRC concludes the following.

1.   The RETRAN-3D Theory and Numerics Manual adequately describes the theory and assumptions made in developing the models and methods used in the code.

2.   The RETRAN-3D Programmer's Manual adequately describes the code structure and how to install the code on a user's computer system.

3.   The RETRAN-3D User's Manual describes the overall code execution procedures and describes in detail how to use the code.

4.   The RETRAN-3D Applications Manual adequately describes the validation of the code application.

3.2   EPRI Verification Release Criteria

The DRC members have reviewed selected source code subroutines in the areas consistent with their RETRAN-3D documentation review assignments. As a result of that review and the review of several test cases, the DRC concludes the following.

1.   The coding is correct with respect to the code specification document.

2.   The numerical solution methods are stable and convergent.

3.   The code is correctly solving the equation set programmed.

3.3   EPRI Validation Release Criteria

The DRC reviewed the analyses reported in the Applications Manual and the results of special test cases that were run to respond to DRC findings. As a result of that review the DRC concludes the following:

1.   The Applications Manual adequately describes the analyses that were performed.

2.   The code is validated to perform the analysis in its application areas by one or more of the following: (a) comparison with relevant experimental and analytical data; (b) comparison against similar calculation techniques; and (c) assuring that all results are consistent with physical assumptions made.

3.   As is the case with any large computer code with a wide range of application, users of RETRAN-3D should be aware of the code's range of application, the code's limitations, and the validation analyses that support the code's qualification.

3.4   EPRI Qualification Release Criteria

The DRC concludes that RETRAN-3D is qualified to perform analyses of operational transients and abnormal events in its intended application areas. In particular, the DRC concludes that RETRAN-3D MOD001f can be used for analysis for which RETRAN-02 MOD5.1 is currently approved by existing SERs and TERs which state in part, " ...acceptable [for]... Chapter 15 of NUREG-0800 and other transients and events as appropriate and necessary for nuclear power plant operation, but excludes Appendix K LOCA analysis." The detailed bases for this conclusion are provided in Section 5.4.

The previous Design Review of RETRAN-02 and subsequent reviews by the NRC lead to a number of findings relative to application of the code. These limitations are identified in the Safety Evaluation Report (SER) and the Technical Evaluation Report (TER) for RETRAN-02. These limitations are of two types: (1) those involving deficiencies in specific models and (2) those requiring further validation for particular applications.

One of the development objectives for RETRAN-3D was to reduce the findings associated with model deficiencies. A detailed discussion of each SER/TER finding and the associated action to eliminate the finding is presented in Appendix C. This satisfies the RETRAN-3D Design Review charge to use the results from previous reviews to determine that any open findings from those reviews have been closed.

3.5   EPRI Evolving Issue Qualification

The final design review objective is to assure that RETRAN-3D MOD001f is capable of performing best-estimate analysis of:

- BWR stability,
- BWR control rod drop,
- PWR control rod ejection,
- PWR steam line break,
- mid-loop operations for PWRs, and
- both full and partial ATWS for both PWRs and BWRs.

The ability to adequately perform these best estimate analyses requires code capabilities beyond those of RETRAN-02. The new RETRAN-3D models such as method of characteristics solution option, three-dimensional kinetics, air/water mixture capability, and thermal non-equilibrium were intended to provide RETRAN-3D with the capability to perform analyses beyond the scope of RETRAN-02. The RETRAN-3D Applications Manual provides the results of analyses intended to qualify the code for these best estimate applications. Because these analyses extend RETRAN-3D beyond the capabilities of RETRAN-02, the DRC members have reviewed them in great detail.

The DRC concludes the following with regard to evolving issue qualification:

C   RETRAN-3D is qualified to provide the core kinetics and system responses in predictions of the PWR Rod Ejection Accident (REA). This conclusion is based on the consistency of the RETRAN-3D results with those of the approved ARROTTA and HERMITE codes.

C   Given the similarity of the kinetics modeling for a BWR Control Rod Drop Accident (CRDA) and a PWR Rod Ejection Accident (REA), RETRAN-3D is considered to be capable of successful application to the BWR CRDA.

C   RETRAN-3D is qualified to perform BWR stability analyses with the following provisions:

-      Void feedback in the multidimensional kinetics model has not been qualified for use in BWRs although the models appear theoretically adequate for this use.

-      The impact of the time step size and numerical solution procedure on predictions of power oscillations and decay ratio has not been quantified.

C   RETRAN-3D is capable of providing the core kinetics and system responses in predictions of the PWR Steam Line Break Accident. This conclusion is based on the consistency of the RETRAN-3D results with those of the approved ARROTTA code.

C   The models in RETRAN-3D are theoretically adequate for BWR full and partial ATWS analyses and most of the component models have been successfully applied to transients with similar phenomena. However, additional qualification of the multidimensional kinetics model for BWR use is needed. The lack of a spatially distributed decay heat model for use with the multidimensional kinetics is a code limitation that affects the accuracy of total core power predictions for some types of partial ATWS analyses.

C   The RETRAN-3D models are theoretically adequate for PWR mid-loop analyses and a demonstration analysis which exhibited the expected trends has been performed. This analysis is documented in Section VIII.2.1 of the RETRAN-3D Applications Manual.

Detailed descriptions of the review of evolving issue qualification are provided in Section 5.5.

3.6   Final Remarks

As a result of the design review process, a number of findings relative to the documentation were resolved either as error corrections or by revising the documentation. A number of additional analyses were also added to Volume 4: Applications Manual at the request of the DRC. Revision 2 of Volumes 1, 2, 3, and 4 (EPRI NP-7450) reflect the content of the reviewed documents with the revisions that closed design review findings.

The RETRAN-3D MOD001f code was reviewed by the DRC. During the review process, a number of coding errors were identified and corrected. Additionally, several revisions to the code were recommended by members of the DRC. These error corrections and code revisions have been implemented in RETRAN-3D MOD002.0 which has been released to the Electric Power Software Center as a Safety Grade Code.

4.0   REVIEW ELEMENTS

4.1   Materials Reviewed

The code specification documents for the review are:

1.   "RETRAN-03 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems Volume 1: Theory and Numerics", EPRI NP-7450, Revision 1, 1995.

2.   "RETRAN-3D - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems Volume 1: Theory and Numerics", EPRI NP-7450, Revision 1, January 1996.

3.   "RETRAN-03 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems Volume 2: Programmer's Manual", EPRI NP-7450-CCML, Revision 1, 1995.

4.   "RETRAN-3D - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems Volume 2: Programmer's Manual", EPRI NP-7450-CCML, Revision 1, January 1996.

5.   "RETRAN-03 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 3: User's Manual", EPRI NP-7450-CCML, Revision 1, 1995.

6.   "RETRAN-3D - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 3: User's Manual", EPRI NP-7450-CCML, Revision 1, January 1996.

7.   "RETRAN-03 - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 4: Verification and Validation", Computer Code Manual Draft, Revision 1, 1995.

8.   "RETRAN-3D - A Program for Transient Thermal-Hydraulic Analysis of Complex Fluid Flow Systems, Volume 4: Applications Manual", Computer Code Manual Draft, Revision 1, May 1996.

9.   Listings of the RETRAN-3D MOD001f source code and associated routines will be used to verify that these specification documents are reflected in the coding.

10.   Validation and qualification analysis results for RETRAN-3D MOD001f which focus on the events for PWRs and BWRs listed in Table 1 and Table 2, respectively, in Appendix A. The evolving issues of interest to EPRI are given in Table 3 of Appendix A.

The earlier versions of the documentation (items 1, 3, 5, and 7 above) were the subjects of the preliminary reviews of RETRAN-3D MOD001f. The final reviews were performed on the revised documents (items 2, 4, 6, and 8 above).

The extensive documentation associated with previous releases of the RETRAN codes and results of previous formal reviews conducted by organizations independent of the RETRAN development were used in the review. These materials include:

•   the SER and TER reports issued by the United States Nuclear Regulatory Commission (USNRC) for RETRAN-01and RETRAN-02 MOD002 through MOD005.1,

•   the records of the RETRAN code maintenance quality assurance procedures used by CSA for the released versions of RETRAN,

•   documentation of applications of RETRAN-03 as given in the Proceedings of International RETRAN Meetings organized by EPRI and CSA, and

- the SER issued by the USNRC for Duke Power's analysis of the steam line break event with the ARROTTA code.

Any other reference material deemed necessary or desirable by the DRC was used in the review. All materials used in the review are identified in Appendix D.

4.2   Conduct of the Review

The first meeting of the DRC took place at the offices of Computer Simulation and Analysis, Incorporated (CSA) in Idaho Falls, Idaho on May 16 and 17, 1995. Present at this meeting were the entire DRC (with the exception of Jim Harrison who was not appointed to the DRC until Spring of 1996), Lance Agee, the EPRI Project Manager for the RETRAN code series, and CSA staff member responsible for the development and qualification of RETRAN-3D. The meeting began with an overview of the CSA Quality Assurance Program. During the remainder of this meeting, the DRC:

- developed a draft Design Review Plan,
- assigned specific review items to each DRC member,
- determined how information will be passed between DRC members,
- determined what specific information is required from CSA,
- determined the detailed presentations we would like the CSA staff to provide,
- clarified the review scope with respect to the 3D neutronic models, and
- assessed whether the DRC resources are adequate to complete the review.

After this meeting, CSA distributed draft documentation for RETRAN-3D and listings of the source code to the DRC members. The draft documentation was items 1, 3, 5, and 7 cited in Section 4.1. The DRC began their review in accordance with the Design Review Plan and communicated their findings to CSA ongoingly.

The second meeting of the DRC took place at the CSA offices on November 13 and 14, 1995. The DRC members stated three major concerns that arose from their reviews of the RETRAN-3D materials.

1.   Complete and final material for RETRAN-3D was not available. In particular, the Programmer's Manual and the Applications Manual were incomplete. The Applications Manual was a particular concern because the DRC felt that it was inadequate for review of the new RETRAN-3D features.

2.   The comparisons of RETRAN-02 and RETRAN-3D analysis results showed significant differences in many cases and the documentation was inadequate to explain or justify these differences. Therefore, the DRC felt that it could not make a statement about RETRAN-3D application to analyses currently approved for RETRAN-02. This concern put design review objective 2A (see Section 2.1) in jeopardy.

3.   The Theory Manual and User's Manual documentation was missing information that was essential for describing the 3D kinetics models.

Following discussions between the DRC, CSA staff, and the EPRI Project Manager, the design review was put on hold until the four RETRAN-3D documents were revised and additional analyses comparing RETRAN-3D and RETRAN-02 were completed. The DRC agreed to continue their review of the earlier versions of the documentation with the understanding that the final review would address the revised documents.

The third meeting of the DRC took place at the CSA offices on June 12 and 13, 1996. Jim Harrison was added to the DRC and assigned to review sections of the RETRAN-3D User's Manual that had originally been assigned to Dan Hughes. At this meeting, the DRC determined that additional validation was required for the 3D kinetics model, the air/water model, and the five-equation model. An action plan was developed by CSA and approved by the DRC. This action plan identified additional CSA analyses and documentation to provide closure to all remaining open findings and DRC concerns.

A summary of the Design Review Findings and the responses that close the findings is provided in Appendix B.

5.0   RESULTS OF THE REVIEW

5.1   Documentation

5.1.1   Volume 1: Theory and Numerical Methods

As specified in the Design Review Plan, the entire text of the Theory and Numerics Manual was reviewed. All findings related to this manual have been satisfactorily resolved and the DRC concludes that the RETRAN-3D Theory and Numerics Manual adequately describes the theory and assumptions made in developing the models and methods used in the code. Revision 2 of Volume 1 reflects the content of the reviewed documents with the revisions that closed design review findings.

5.1.2   Volume 2: Programmer's Manual

As specified in the Design Review Plan, the entire text of the Programmer's Manual was reviewed. All findings related to this manual have been satisfactorily resolved and the DRC concludes that the RETRAN-3D Programmer's Manual adequately describes how to install the code on a user's computer system. Revision 2 of Volume 2 reflects the content of the reviewed documents with the revisions that closed design review findings.

5.1.3 Volume 3: User's Manual

As specified in the Design Review Plan, the entire text of the User's Manual was reviewed. All findings related to this manual have been satisfactorily resolved and the DRC concludes that the RETRAN-3D User's Manual describes in detail how to use the code. Revision 2 of Volume 3 reflects the content of the reviewed documents with the revisions that closed design review findings.

5.1.4 Volume 4: Applications Manual

As specified in the Design Review Plan, the entire text of the Applications Manual was reviewed. All findings related to this manual have been satisfactorily resolved and the DRC concludes that the RETRAN-3D Applications Manual adequately describes the validation of the code application. Revision 2 of Volume 4 reflects the content of the reviewed documents with the revisions that closed design review findings.

5.2 Verification of Source Code

Individuals on the DRC have reviewed selected source code subroutines consistent with their RETRAN-3D documentation review assignments. As a result of that review and the review of test cases, the DRC concludes the following.

1. The coding is correct with respect to the code specification document.
2. The numerical solution methods are stable and convergent.
3. The code is correctly solving the equation set programmed.

5.3 Validation

5.3.1 Standard Models and Methods

Validation of the RETRAN-3D code is described in the Applications Manual of the code documentation. Comparisons of RETRAN-3D to relevant test data and to predictions of similar calculational techniques are used in the validation. Because of its long history and extensive usage, the RETRAN-02 code has an extensive validation base. By demonstrating close agreement between RETRAN-02 and RETRAN-3D for a range of analyses, validation of RETRAN-3D is significantly extended.

The analyses in the Applications Manual of the RETRAN-3D code documentation exercise a wide range of models and methods but by no means an exhaustive set of all the possible combinations. Results of the ten sample problems calculated by RETRAN-02 were compared to results calculated by RETRAN-3D.

The system transient analyses in the Applications Manual consisted of seven BWR events and ten PWR events for which analyses were compared with RETRAN-02.   Most of the analyses with RETRAN-3D were performed with the same models and methods used by RETRAN-02. In addition, 4 PWR and 15 BWR events were analyzed with RETRAN-3D and compared with measured data.   The analyses presented in the Applications Manual provide a reasonable validation base for application of RETRAN-3D to the transients in Tables 1 and 2 of the Design Review Plan (see Appendix A).

The RETRAN-3D code predictions compared favorably with relevant test data for operational transients and with predictions of similar calculational techniques (RETRAN-02) for transients of the type shown in Tables 1 and 2 of the Design Review Plan (see Appendix A).

5.3.2   Evolving Issues Models and Methods

The five-equation solution was used with a number of void fraction and separate effects data comparisons. Additionally, results of PWR and BWR system analyses using the five-equation model were compared against four-equation results.

The method of characteristics (MOC) option was used with the five-equation option to make predictions of the Peach Bottom and Vermont Yankee stability tests.

The noncondensable gases and separate effects heat transfer models that were added to RETRAN-3D for use in evolving issue analyses do not have a large validation base. However, all RETRAN-3D analyses performed with these models compared favorably with the relevant benchmark data.

A major new model added to RETRAN-3D for use in evolving issue analyses is the multidimensional kinetics solution that was created by adding the ARROTTA solution methods to RETRAN-3D. The stand alone ARROTTA code has its own validation base[5-1, 5-2, 5-3, and 5-4] and, by demonstrating consistency, this base can be extended to RETRAN-3D. The analyses available to validate the 3D kinetics model were:

- •   PWR Rod Ejection Accident Comparison to ARROTTA,
- •   PWR Steam Line Break (SLB) Comparison to ARROTTA,
- •   HERMITE/ARROTTA Rod Ejection Accident (REA) Comparison,
- •   NEACRP Benchmark REA Case A1 (Hot Zero Power), and
- •   NEACRP Benchmark REA Case A2 (Hot Full Power).

The SLB and REA analyses utilize the multidimensional kinetics model, water density and fuel temperature feedback models, fuel rod model and coupling of the kinetics and fuel rod model to the system thermal hydraulics. In addition the boron transport and cross section feedback were exercised in the SLB event. These analyses are a significant validation base for the 3D kinetics and associated models. There was no analysis in the material reviewed that utilized void feedback on cross sections in the multidimensional kinetics. One analysis which exercised the void feedback model was performed by the review team with satisfactory results. While void

feedback is very similar to moderator density feedback for which validation analyses were performed, there is a need for BWR specific analyses utilizing the multidimensional kinetics.

5.4   Qualification for Standard Applications

5.4.1   PWR Transients

The qualification of RETRAN-3D MOD00f1 to analyze PWR transients of the types shown in Table 1 of the Design Review Plan (See Appendix A) was assessed as part of the design review. The previous version of RETRAN (RETRAN-02) has been widely and successfully used for PWR SAR chapter 15 transient analyses and the comparison of RETRAN-3D to RETRAN-02 allows the qualification of RETRAN-02 to be extended to RETRAN-3D.

Several operational transient analyses in the RETRAN-3D Applications Manual compare RETRAN-02 and RETRAN-3D results. Each of these analyses provides secondary qualification information for portions for the fluid field equations, wall heat transfer equations, point kinetics and energy generation equations, component and auxiliary models. It should be noted that some of the RETRAN-02/RETRAN-3D comparison analyses initially produced different results. These cases were extensively examined to find the reason for the differences. When the cause of these differences were identified and modifications were made to either the input models or codes to ensure consistent modeling, then agreement between the results for the two codes was generally very good. Other analyses which showed only small differences between RETRAN-02 and RETRAN-3D were not examined to the same degree.

The PWR analyses comparing RETRAN-02 and RETRAN-3D in Section VI.3 of the Applications Manual are:

C   ANO-2 Turbine Trip: This transient is a moderate test for the wall heat transfer and heat conductors and inventory tracking under a decrease in secondary heat removal. The RETRAN-02 and RETRAN-3D analyses are in excellent agreement with some small difference in the steam generator level late in the transient that are attributable to improvements in slip modeling in RETRAN-3D.

C   Calvert Cliffs Steam Line Break: This transient is a severe test of secondary inventory tracking and primary to secondary heat transfer. The comparisons revealed an error in the RETRAN-3D implementation of the Wilson bubble rise model velocity calculation in the pressurizer. With this error corrected and consistent modeling between RETRAN-02 and RETRAN-3D the comparisons were in good agreement. Most of the remaining differences were traced to differences in the treatment of kinetic energy, phase slip and enthalpy transport and excellent agreement is obtained when these differences are eliminated. However, the RETRAN-3D treatment of slip and enthalpy transport are improvements over the RETRAN-02 models so the differences between the codes with these models activated should be considered typical of the results expected with the improved models.

C   **PWR Loss of Flow**: This event is a severe loss of flow leading to a decrease in heat removal. The agreement between RETRAN-02 and RETRAN-3D was excellent for all parameters.

C   **Trojan Loss of Feedwater ATWS**: This event is a severe loss of heat sink transient that tests the point kinetic and power generation models as well as the pressurizer and heat transfer models. The agreement between RETRAN-02 and RETRAN-3D (four-equation model) is good considering the severity of the event and the differences are attributable to the model differences discussed above. This event was also analyzed with RETRAN-3D using the five-equation option in the secondary side of the steam generators. The four-equation and five-equation results are very close for the first half of the transient. The differences in the latter half of the transient are reasonably explained by increased primary to secondary heat transfer for the five-equation model and subsequent earlier dry out of the steam generator leading to a more rapid decrease in primary to secondary heat transfer. This is a very severe transient and use of the five-equation model is expected to produce the observed changes in results.

C   **Prairie Island Steam Generator Tube Rupture**: This event results in a significant primary side temperature and pressure transient. Examination of this event revealed the potential for differences between RETRAN-02 and RETRAN-3D due to the improved control block modeling in RETRAN-3D. In RETRAN-3D the order in which control blocks are numbered does not impact the calculation but this was not true in RETRAN-02. Many RETRAN-02 decks were created in which proper operation depended upon the control block order. Such modeling is not a good practice and must be corrected to compare RETRAN-02 to RETRAN-3D. After correcting the control block modeling, comparisons between RETRAN-02 and RETRAN-3D (four-equation model) showed small differences that were traced to the differences in treatment of kinetic energy and enthalpy transport. Excellent agreement between RETRAN-02 and RETRAN-3D is obtained when these differences are eliminated. This event was also analyzed with RETRAN-3D using the five-equation option in the secondary side of the steam generators. The four-equation and five-equation RETRAN-3D results show good agreement.

C   **Three Mile Island Loss Of Feedwater**: The detailed examination of the differences between RETRAN-02 and RETRAN-3D for this event resulted in identifying an error in the version of RETRAN-02 used for the analysis. This error allowed the pressurizer heaters to cycle on and off every other time step. With the error corrected and enthalpy transport turned off in both codes, excellent agreement was obtained. The difference in enthalpy transport modeling between the codes results in slightly larger differences when enthalpy transport is activated.

C   **Almaraz Turbine Trip**: This transient is a moderate test for the wall heat transfer and heat conductors and inventory tracking under a decrease in secondary heat removal. The RETRAN-02 and RETRAN-3D analyses are in excellent agreement with some small difference in the steam generator responses, when enthalpy transport is used, that are attributable to model differences between RETRAN-02 and RETRAN-3D previously discussed.

C   <u>KEPCO KNU-1 Steam Generator Tube Rupture</u>: This event results in a significant primary side temperature and pressure transient. The RETRAN-02 and RETRAN-3D analyses are in excellent agreement with only small differences that are due to the model differences between RETRAN-02 and RETRAN-3D previously discussed.

C   <u>KNU-2 Loss Of Normal Feedwater</u>: The results of this comparison were consistent with that encountered in previously described transients. That is, the agreement between RETRAN-02 and RETRAN-3D were excellent when differences in enthalpy transport and slip models in the steam generator secondary side were eliminated. When enthalpy transport and slip were activated, a slightly larger difference in results is seen.

C   <u>Yonggwang 1 Turbine Trip</u>: This event results in a significant secondary side pressure rise and resulting primary cold leg temperature transient. The RETRAN-02 and RETRAN-3D analyses are in excellent agreement throughout the transient on all parameters.

Four PWR operational transient analyses in the Applications Manual of the RETRAN-3D documentation were compared to measured plant data. Direct comparison to measured data is highly desirable for code qualification but entails a significant analysis and interpretation burden. In addition, the quality of data measured with normal plant operating instruments is not often known. The analyses in the Applications Manual were performed with utility developed models and it is likely that the level of effort applied varied between the various analyses. These considerations mean that the cause of differences between code prediction and measure data can not always be readily determined or eliminated.

The PWR operational transient analyses comparing RETRAN-3D to measured data in Section VII.3 of the Applications Manual are:

C   <u>KORI Nuclear Unit 1 Loss Of All Offsite Power</u>: The RETRAN-02 and RETRAN-3D predictions of the steam generator secondary water level are in excellent agreement with the measured data. The steam generator pressure predictions are in good agreement with the measured data. The agreement between the predicted and measured recirculation loop average temperature, pressurizer pressure and level are consistent with the differences in steam generator pressure and support the accuracy of the primary-to-secondary heat transfer modeling. The primary system primary coolant loop flow predictions are in good agreement with the measured data.

C   <u>KORI Nuclear Unit 4 Large Load Reduction Test</u>: The RETRAN-02 and RETRAN-3D transient predictions are in very good agreement but the agreement with the measured data is only fair. In particular the steam generator secondary pressure predictions tend to be significantly above the measured data. The impact of the higher secondary pressure would be expected to raise the predicted cold leg temperature as was observed. This cause of model over prediction of steam generator secondary pressure is attributed to the modeling used for the steam dump system.

C   <u>Comanche Peal Steam Electric Station Load Rejection</u>: The RETRAN-02 and RETRAN-3D analyses employed a relatively coarse steam generator secondary model and the steam generator water level predictions were impacted such that only the trends were in agreement with the measured data. The steam generator secondary side pressure was in reasonable agreement with the measured data but tended to be on the high side and this is attributed to incomplete modeling of auxiliary systems. Despite the secondary side differences, the predicted primary side conditions are in good agreement with the measured data.

C   <u>KORI Nuclear Unit 2 Multiple Failure Event</u>: This is a relatively long and complex transient involving a large change in system thermal-hydraulic conditions. The RETRAN-3D transient predictions of both primary and secondary side pressure are quite good throughout the simulation considering the complexity of the event and relatively coarse model. The primary coolant loop temperature predictions are also in good agreement with the measured data. Prediction of steam generator and pressurizer level are in general agreement with the measured data.

The transient predictions are in agreement with the measured data for each of the four analyses. All of the PWR operational transient analyses show excellent agreement between RETRAN-02 and RETRAN-3D. Most of the small differences between RETRAN-02 and RETRAN-3D are found to be due to new or improved methods and models in RETRAN-3D. Based upon these comparisons, the level of qualification of RETRAN-02 for PWR analyses has not been compromised by the new models and methods in RETRAN-3D and has been extended. This review shows that RETRAN-3D MOD001f is qualified to perform the analyses for which RETRAN-02 MOD5.1 has been approved and to perform the analyses shown in Table 1 of the Design Review Plan (See Appendix A).

5.4.2   BWR Transients

The qualification of RETRAN-3D MOD001f to analyze BWR transients of the types shown in Table 2 of the Design Review Plan (See Appendix A) was assessed as part of the design review. The previous version of RETRAN (RETRAN-02) has been widely and successfully used for BWR safety analyses and the comparison of RETRAN-3D to RETRAN-02 for the seven BWR events in the Applications Manual allows the qualification of RETRAN-02 to be extended to RETRAN-3D.

The BWR analyses comparing RETRAN-02 and RETRAN-3D in Section VI.2 of the Applications Manual are:

C   <u>Susquehanna Feedwater Controller Failure</u>: Comparisons between RETRAN-02 and RETRAN-3D for this event revealed some control system modeling which caused a high sensitivity to time step size and control system initialization. After modifications to the control blocks to reduce the sensitivity, the RETRAN-02 and RETRAN-3D results showed excellent agreement.

C   Susquehanna Feedwater heater Failure: The RETRAN-3D analysis of this event produced reasonable results that were consistent with expectations. Comparisons between RETRAN-02 and RETRAN-3D showed excellent agreement.

C   Oyster Creek Feedwater Controller Failure: The results for RETRAN-02 and RETRAN-3D using the four-equation model are almost identical for this transient with only small differences in downcomer mixture level which are probably due to slight differences in the slip model. This analysis was also performed with the five-equation model in RETRAN-3D and produced reasonable results. The five-equation model results in a lower peak reactor power and correspondingly lower vessel pressure. The lower power in the five-equation results was traced to a higher core void content during the transient with the five-equation model. The same one-dimensional neutronics cross section file was used for both the four-equation and five-equation analyses, but consistency would require the cross section void dependence to reflect the model used to evaluate the core voids.

C   Cofrentes MSIV Trip: This event was a complete closure of all MSIVs from full power with a scram on MSIV position. The results of the RETRAN-02 and RETRAN-3D (four-equations model) are nearly coincident. This event was also analyzed with the five-equation model in RETRAN-3D which also gave close agreement.

C   BWR ATWS: Comparison of RETRAN-02 and RETRAN-3D for this event resulted in identifying a RETRAN-02 code error in the decay heat portion of direct moderator heating for the specific model used and a RETRAN-3D code error preventing slip from resuming in a junction after its fluid conditions became single-phase and then returned to two-phase. The RETRAN-02 and RETRAN-3D results for this event are extremely close for the first thirty seconds of this event after which there is a small shift in timing of the cycling of the relief valves but no significant differences are observed.

C   River Bend Two Recirculation Pump Trip: Comparison of RETRAN-02 and RETRAN-3D results for this event show excellent agreement with no significant differences.

C   Peach Bottom Turbine Trip: Comparison of RETRAN-02 and RETRAN-3D (four-equation model) results for this event show very good agreement. There is a slight difference in steam dome pressure that was found to be caused, in part, by the difference in treatment of junction kinetic energy between the codes. The kinetic energy difference is normally negligible but the small junction flow areas in the explicit representation of bypass and safety/relief valves used in this model accentuated the difference. Other very slight differences were caused by the input controller conditions in the RETRAN-02 model. This analysis was also performed with the five-equation model in RETRAN-3D which showed good agreement the other analyses. The peak reactor power predicted by the five-equation model was less and occurred slightly later than with the four-equation model. This difference is primarily due the more rigorous treatment of subcooled boiling in the core with the five-equation model.

The BWR operational transient analyses comparing RETRAN-3D to measured data in Section VII.2 of the Applications Manual are:

C   Cofrentes HPCS Injection: This is a relatively mild event that tested the ability of RETRAN-3D to track vessel water level, pressure and power after the introduction of cold water into the reactor and the subsequent controller actions to restore equilibrium. The RETRAN-3D predictions agreed well with the observed plant data on both timing and magnitude of changes in observed parameters.

C   Cofrentes FW Controller Failure: This is a complex event which tracked the reactor from full power to zero power conditions over a period of about 100 seconds. The RETRAN-3D analysis showed good agreement with the core power and flow following the recirculation pump transfer to low speed. The predictions of reactor water level and pressure exhibited the correct trends and were in fair agreement with observed data on the magnitude and timing.

C   Laguna Verde Generator Load Rejection: The RETRAN-3D analysis of this pressurization event was in fair agreement with the observed data.

C   Laguna Verde MSIV Closure: The RETRAN-3D analysis of this pressurization event produced excellent agreement with the observed pressure response and fair agreement with the observed data for core flow and vessel water level.

C   BWR-5 Pressure Setpoint Change: This is a very mild transient but tested the interaction of control systems, thermal-hydraulics and the 1-D reactor kinetics. The RETRAN-3D predictions of the response of reactor power, pressure, steam and feedwater flow were in good agreement with the observed data.

C   BWR-5 Level Setpoint Change: The RETRAN-3D predictions were in good agreement with the observed data.

    BWR-5 One PLR Pump Trip: This transient tracks the reactor from full power and flow to a natural circulation condition testing the interaction of the reactor thermal-hydraulics and the 1-D reactor kinetics. The RETRAN-3D predictions of the response of reactor power, pressure, steam flow and recirculation flow were in fair agreement with the observed data. This analysis was also performed using the five-equation option (with MOC) in RETRAN-3D and the agreement with observed data was very similar to the four-equation results.

C   BWR-5 All MSIV Closure: The RETRAN-3D predictions were in fair agreement with the observed data. The results with four-equation and five-equation options in RETRAN-3D were similar.

C   BWR-5 Load Rejection with Bypass: The RETRAN-3D predictions were in fair agreement with the observed data. The results with four-equation and five-equation (with MOC) options in RETRAN-3D were similar.

C   <u>BWR-5 Single MSIV Closure</u>: The RETRAN-3D predictions were in good agreement with the observed data.

C   <u>Cofrentes Level Setpoint Change</u>: The RETRAN-3D predictions were in fair agreement with the observed data.

C   <u>Cofrentes Feedwater Pump Trip</u>: The RETRAN-3D predictions were in good agreement with the observed data.

C   <u>Cofrentes Recirculation Pump Low-Speed Transfer</u>: The RETRAN-3D core flow and core power predictions were in very good agreement with the observed data. Vessel water level predictions agreed well with data for the first 25 seconds. The plant data shows an increase in water level at about 25 seconds while the RETRAN-3D predictions show a continual level decrease.

C   <u>Cofrentes Turbine Trip</u>: The RETRAN-3D predictions of pressure, steam flow and core flow agreed with the observed data. The predicted vessel water level agreed with the trends in the measured data but underpredicted the minimum measured vessel level.

C   <u>Cofrentes Load Rejection With Partial Bypass Failure</u>: The RETRAN-3D predictions agreed well with the observed reactor pressure and core flow responses. The comparisons of predicted and observed steam flow and vessel level showed good agreement.

Comparison of RETRAN-3D to RETRAN-02 for the seven BWR events in the Applications Manual shows excellent agreement and most of the small differences between RETRAN-02 and RETRAN-3D were found to be due to new or improved methods and models in RETRAN-3D. Based upon these comparisons, the qualification of RETRAN-02 for BWR analyses has not been compromised by the new models and methods in RETRAN-3D. Comparison to measured data for 15 events further demonstrated that RETRAN-3D is an effective tool for analyzing BWR operational transients. This review shows that RETRAN-3D MOD001f is qualified to perform the analyses for which RETRAN-02 MOD5.1 has been approved and to perform the analyses shown in Table 2 of the Design Review Plan (See Appendix A). However, currently there are no analyses qualifying the multidimensional kinetics model for use in BWR analyses.

5.5   Qualification for Application to Evolving Issues

5.5.1   BWR Stability

The Peach Bottom stability tests were analyzed with RETRAN-03 (a predecessor to RETRAN-3D) using the MOC model with point kinetics. The results of the Peach Bottom stability tests were in reasonable agreement with the measured data however the low decay ratios in these tests limit their usefulness in code qualification.

RETRAN-3D was used to perform analyses of the Vermont Yankee stability tests and the predicted core decay ratios were in reasonable agreement with the experiment but with a bias to under prediction. The RETRAN-3D calculations were also compared to the LAPUR code which is widely use for BWR core decay ratio predictions. The RETRAN-3D and LAPUR decay ratios agreed within the expected uncertainty in the LAPUR calculation with RETRAN-3D predictions lower than those of LAPUR. The Vermont Yankee analysis used the MOC option in the core region and the one-dimensional neutron kinetics option.

The Peach Bottom and Vermont Yankee stability analyses show that RETRAN-3D has the capability of performing BWR stability analyses. No stability analyses are available using the multidimensional kinetics model which is needed for analyses of potential "regional" power oscillations in a BWR core. Never-the-less, the RETRAN-3D model appears theoretically adequate for use in "regional" oscillation analyses. In addition, an investigation of the impact of the RETRAN-3D numerical solution procedure on decay ratio and power oscillation calculations was not available but is needed to fully qualify the code for this use.

5.5.2   BWR Control Rod Drop

No analyses specific to a BWR control rod drop accident have been performed with RETRAN-3D using the multidimensional kinetics model. However, the BWR control rod drop and PWR rod ejection accident require identical phenomena to be modeled. Several analyses were performed for the PWR rod ejection accident and the generality of the RETRAN-3D models gives reason to expect that RETRAN-3D can be successfully used for a BWR control rod drop accident. Given the similarity of the kinetics modeling for a BWR Control Rod Drop Accident and a PWR REA, it is concluded that RETRAN-3D is capable of successful application to the BWR CRDA .

5.5.3   PWR Rod Ejection

The qualification basis for RETRAN-3D to perform a PWR Rod Ejection Accident is the most complete of the evolving issue analyses. Four separate comparison analyses are available. The comparison analyses are:

C   PWR Rod Ejection Accident Comparison to ARROTTA: This is an analysis of a simple PWR quarter-core involving the rapid removal of a high worth, off center control rod from an initial high power level. The RETRAN-3D 8 channel thermal-hydraulic model was constructed to match the ARROTTA input model as closely as possible. The analyses used moderator density and Doppler feedback mechanisms. The comparison of normalized core power response between ARROTTA and RETRAN-3D is excellent.

C   HERMITE/ARROTTA Rod Ejection Accident Comparison: This is a representative full size PWR rod ejection accident analysis from hot, zero power conditions which compares the RETRAN-3D results to those obtained from the HERMITE and ARROTTA codes. Excellent agreement between all three codes was shown for the transient reactor power

response and power distribution. The HERMITE and RETRAN-3D fuel temperature response also agreed closely. The ARROTTA fuel temperature results showed differences from those of RETRAN-3D and HERMITE that are due to differences in the fuel rod model.

C   NEACRP Benchmark REA: The NEACRP benchmark is a PWR REA event for assessing three-dimensional transient codes for LWRs. The thermal-hydraulic feedback effect on the cross-section model is prescribed as part of the problem to maintain the same formulation between codes. Problem A1 is initiated from hot, zero power conditions and problem A2 is initiated from hot, full power initial conditions. The RETRAN-3D calculations for conditions A1 and A2 were compared to ARROTTA results. For the A1 calculation, the RETRAN-3D and ARROTTA channel power distributions were essentially identical throughout the transient as can be expected since the same models are used. For the A2 conditions there were slight difference in the initial channel power distribution for ARROTTA and RETRAN-3D due to differences in the thermal-hydraulic feedback model but these differences were not significant and did not increase during the transient. The core transient power response for conditions A1 and A2 showed close agreement between ARROTTA and RETRAN-3D with a slight difference between RETRAN-3D and ARROTTA after the peak power for the A2 condition. The overall agreement between RETRAN-3D and ARROTTA for both conditions was excellent. The RETRAN-3D results were also in good agreement with other reported code results for this event (PANTHER).

Both HERMITE and ARROTTA have been approved for use in PWR REA analyses by the NRC. Based upon the consistency of the RETRAN-3D calculations with ARROTTA and HERMITE, it is concluded that the RETRAN-3D code is qualified for providing the core kinetics and system responses in a PWR rod ejection accident.

5.5.4   PWR Steam Line Break

One analysis of a PWR steam line break utilizing the multidimensional kinetic model has been performed with RETRAN-3D with two different initial conditions.

C   PWR Steam Line Break Comparison to ARROTTA: This analysis uses a simple plenum-to-plenum model to facilitate comparison of RETRAN-3D to ARROTTA. The analysis tested the multidimensional kinetics models, water density, fuel temperature and boron cross section feedback and coupling of the neutronics and power generation to the thermal-hydraulics. The analysis was initiated from a low power (10 kW) and from a higher power (10 MW) initial condition. The RETRAN-3D and ARROTTA calculations of the core power response are in excellent agreement although the ARROTTA power is slightly lower after the peak power occurs in both analyses. The difference in the ARROTTA and RETRAN-3D power response after the peak power was traced to differences in the fuel rod heat conduction solutions between the codes.

RETRAN-3D has been tested on other steam line break and related analyses (although the multidimensional kinetics model was not used) in which the complete reactor system was simulated. Coupled with the plenum-to-plenum analysis using the multidimensional kinetics, it is reasonable to expect that RETRAN-3D is capable of providing the core kinetics and system responses in PWR Steam Line Break event.

5.5.5   PWR Mid-Loop Operations

The RETRAN-3D models are theoretically adequate for PWR mid-loop operation analyses. A demonstration PWR Mid-Loop Operation analysis performed with RETRAN-3D is included in Section VIII.2.1 of the Applications Manual. The RETRAN-3D analysis has not been compared with any known solutions but it exhibited the expected trends.

5.5.6   PWR Full and Partial ATWS

A PWR ATWS sample problem was executed with RETRAN-3D and the Trojan Loss of Feedwater ATWS analysis with RETRAN-3D was in close agreement with RETRAN-02. Neither of these analyses used the multidimensional kinetics or five-equation solution options. Although no application of RETRAN-3D with the new models to PWR ATWS was available, the models in RETRAN-3D appear theoretically adequate for this use and the component models have been successfully applied to transients with similar phenomena.

5.5.7   BWR Full and Partial ATWS

RETRAN-3D was compared to RETRAN-02 for a BWR ATWS analysis with good agreement. This analysis did not use the multidimensional kinetics or five-equation solution options. Although no application of RETRAN-3D with the new models to BWR ATWS was available, the models in RETRAN-3D appear theoretically adequate for this use and have been successfully applied to transients with similar phenomena. One limitation in the RETRAN-3D is that spatially distributed (based on operational power distribution history) decay heat is not included in the multidimensional kinetics model. For some types of BWR partial ATWS analyses the spatial decay heat distribution can have an important impact.

5.6   References for Section 5.0

5-1   Rohan, P. E., and Wagner, S. G., "ARROTTA-HERMITE Code Comparison", Electric Power Research Institute, EPRI-NP-6614, December 1989.

5-2   Lee, R. R., et al., "Utility Implementation of EPRI Rod Ejection Accident Methodology", Electric Power Research Institute, EPRI-TR-100520, April 1992.

5-3   Huang, P. H., Yang, J. T., and Wu, J. Y., "Qualification of the ARROTTA Code for Light Water Reactor Accident Analysis", <u>Nuclear Technology</u>, Vol. 108, October 1994.

5-4   DPC-NE-30001-A, "Multidimensional Reactor Transient and Safety Analysis Physics Parameter Methodology", Duke Power Company, November 1991.

6.0   UNRESOLVED ISSUES

There are no unresolved issues resulting from this Design Review of RETRAN-3D MOD001f.

7.0   RECOMMENDATIONS

1.   The RETRAN-3D MOD001f code was reviewed by the DRC. During the review process, a number of coding errors were identified and corrected. Additionally, several revisions to the code were recommended by members of the DRC. These error corrections and code revisions have been implemented in RETRAN-3D MOD002.0 which has been released to the Electric Power Software Center as a Safety Grade Code. Revision 2 of Volumes 1, 2, 3, and 4 (EPRI NP-7450) reflect the content of the reviewed documents with the revisions that closed design review findings. The DRC recommends that Volume 4: Applications Manual identify which event analyses were performed with the RETRAN-3D MOD001f and which were performed with RETRAN-3D MOD002.0.

2.   The RETRAN-02 documentation includes "Volume 5: Modeling Guidelines". EPRI has also developed "BWR Event Analysis Guidelines" and "PWR Event Analysis Guidelines" documents as part of the Reactor Analysis Support Package (RASP) documentation. These documents were not reviewed as part of the RETRAN-3D MOD001f Design Review. However, these modeling and event analysis guideline documents have proven to be quite useful to users who are developing or validating RETRAN-02 models. The DRC recommends development of either: (a) a modeling guideline document for RETRAN-3D; or (b) a supplement to the existing modeling and event analysis guidelines to address the extended application of RETRAN-3D. Additional verification and validation analyses may be required in order to develop these guidelines. The RETRAN-3D modeling guideline document should provide support to the RETRAN-3D user for correctly applying the three-dimensional neutronics model, the five-equation solution model, the air/water model, the method of characteristics model, and for developing specific plant models for application to evolving issues, such as:

•   BWR stability,
•   BWR control rod drop and PWR control rod ejection,
•   PWR steam line break,
•   mid-loop operations for PWRs, and
•   PWR full and partial ATWS and BWR full and partial ATWS.

3.	The DRC has noted that void feedback in the multidimensional kinetics model has not been qualified for use in BWRs although the models appear theoretically adequate for this use. The DRC recommends that verification and validation RETRAN-3D analyses using the multidimensional kinetics model in BWR simulations be performed. This should include comparison to measured BWR plant data such as the Peach Bottom Unit 2 turbine trip tests performed at the end of Cycle 2.

4.	The DRC has noted that BWR stability analyses have not been performed with the multidimensional kinetics model and that the impact of the time step size and numerical solution procedure on predictions of power oscillations and decay ratio has not been quantified. The DRC recommends that RETRAN-3D BWR stability analyses using the multidimensional kinetics model in BWR simulations be performed. This should include comparison to measured BWR plant data such as:

	•	Peach Bottom Unit 2 stability tests performed at the end of Cycle 2,
	•	Vermont Yankee Limit Cycle Instability,
	•	Leibstadt plant stability test,
	•	the LaSalle plant instability event, and
	•	the WNP-2 instability event.

5.	The DRC noted that, given the similarity of the kinetics modeling for a BWR Control Rod Drop Accident (CRDA) and a PWR Rod Ejection Accident (REA), RETRAN-3D is considered to be capable of successful application to the BWR CRDA. The DRC recommends that a demonstration analysis of the BWR CRDA event be performed.

6.	Applicability of RETRAN-3D to PWR mid-loop operation was validated by a demonstration analysis. The DRC recommends additional analyses including comparison to plant data and/or predictions of other computer codes.

7.	None of the RETRAN-3D analyses provided to the DRC have counter current flow so this capability has not been demonstrated. The DRC recommends analyses comparing RETRAN-3D predictions to counter current flow experimental data.

8.	The RETRAN-3D momentum equation solution does not include the logic to limit the flow in a counter current flow junction to the counter current flow limit (CCFL). The DRC recommends that this restriction be relaxed by modification to the junction momentum model.

9.	The lack of a spatially distributed decay heat model for use with the multidimensional kinetics is a code limitation that affects the accuracy of total core power predictions for some types of partial ATWS analyses. The DRC recommends that this restriction be relaxed by extending the current RETRAN-3D decay heat model.

10.	The relatively loose numerical coupling of the heat transfer to the thermal-hydraulics is a code limitation for some applications. The DRC recommends that this restriction be relaxed by implementing a tighter numerical coupling.

11.   When using the noncondensable model, the relative concentrations of the noncondensable mixture can not change during a transient event. The DRC recommends that this code limitation be clearly stated in the RETRAN-3D documentation.

12.   RETRAN-3D is not applicable to situations with open flow fields where viscous or turbulent shear stresses are dominant. The DRC recommends that this code limitation be clearly stated in the RETRAN-3D documentation.

13.   Superheated vapor in the presence of subcooled liquid is not permitted. At least one phase must be at saturation temperature. Since this could be a factor in the simulation of some events, the DRC recommends that this code limitation be clearly stated in the RETRAN-3D documentation.