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October 2005

RETRAN-02 Modeling and Qualification For Westinghouse Pressurized Water Reactors Non-LOCA Safety Analyses

Supplement 1-Thick Metal Mass Heat Transfer Model and NOTRUMP-Based Steam Generator Mass Calculation Method

Westinghouse

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RETRAN-02 Modeling and Qualification For Westinghouse Pressurized Water Reactors Non-LOCA Safety Analyses

Supplement 1 – Thick Metal Mass Heat Transfer Model And NOTRUMP-Based Steam Generator Mass Calculation Method

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NOS. 171 AND 159 TO

FACILITY OPERATING LICENSE NOS. NPF-76 AND NPF-80

STP NUCLEAR OPERATING COMPANY, ET AL.

SOUTH TEXAS PROJECT, UNITS 1 AND 2

DOCKET NOS. 50-498 AND 50-499

1.0 INTRODUCTION

In a letter dated May 13, 2003, as supplemented by letters dated October 6, 2004, November 30, 2004, and January 20, 2005 (References 1 through 4, respectively), South Texas Project Nuclear Operating Company (the licensee) requested revisions to the RETRAN-02 methodology that is used to evaluate certain design basis transients and accidents for the South Texas Project (STP), Units 1 and 2. In particular, the licensee believes that the current RETRAN-02 methodology is overly conservative for evaluation of certain design basis events involving loss of normal feedwater (LOFW), loss of offsite power (LOOP), and feedwater line breaks (FWLB). These events all involve reduction in the ability of the steam generators (SGs) to remove reactor heat causing the reactor temperature and pressure to increase.

The supplements dated October 6, 2004, November 30, 2004, and January 20, 2005, provided additional information that clarified the application, did not expand the scope of the application as originally noticed, and did not change the Nuclear Regulatory Commission (NRC) staff's original proposed no significant hazards consideration determination as published in the *Federal Register* on November 12, 2003 (68 FR 64138).

2.0 REGULATORY EVALUATION

The staff reviewed the licensee's request in accordance with the guidance in the Standard Review Plan (SRP) (Reference 5) Sections 15.2.6 "Loss of Nonemergency AC Power to the Station Auxiliaries," 15.2.7 "Loss of Normal Feedwater Flow," and 15.2.8 "Feedwater System Pipe Breaks Inside and Outside Containment."

The LOFW and the LOOP are classified as incidents of moderate frequency. The key SRP acceptance criteria for events of moderate frequency are summarized as follows:

1. Pressures in the reactor coolant system (RCS) and in the main steam system should be maintained below 110 percent of the design pressure.

2. Fuel cladding integrity shall be maintained by ensuring that the departure from nucleate boiling ratio (DNBR) limit is maintained to ensure a 95 percent

probability that critical heat flux (CHF) will not occur with a confidence of 95 percent for the hottest fuel pins of the reactor core.

The occurrence of FWLB up to the double ended guillotine severance of a main feedwater line are considered by the NRC staff to be design basis accidents. The key SRP acceptance criteria for the analysis of FWLBs are as follows:

1. Pressure in the RCS and main steam system should be maintained below 110 percent of the design pressures for most break sizes and below 120 percent of the design pressures for very low probability events such as the occurrence of a double ended guillotine break.

2. The potential for core damage that may occur during the transient is evaluated on the basis that it is acceptable if the minimum DNBR remains above the 95/95 DNBR limit. If fuel damage is calculated to occur, the damage must be of sufficiently limited extent that the core will remain in place and intact with no loss of core cooling capability.

3. Any activity release must be such that the calculated dose at the site boundary is a small fraction of the guidelines in Part 100 of Title 10 of the Code of Federal Regulations (10 CFR).

Computer code methodology used for analyses of design basis transients and accidents including the computer code input and calculational assumptions are to be reviewed and assured to be conservative for showing compliance with the acceptance criteria. The NRC staff concludes that, when the licensee utilizes the revised methodology, the licensee will meet the acceptance criteria.

3.0 TECHNICAL EVALUATION

The licensee believes that the current analyses for LOFW, LOOP, FWLB events are too conservative in the following two respects: (1) in the heat absorption from the reactor coolant to the thick structural metal of the reactor system pressure boundary and (2) in the determination of initial SG water mass.

The current methodology, which the licensee uses to evaluate LOFW, LOOP, and FWLB is described in WCAP-14882-P-A "RETRAN-02, Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analysis" (Reference 6) which has been approved by the NRC staff. RETRAN-02 is a flexible, general purpose, thermal/hydraulic computer code that is used to evaluate the effect of various upset reactor conditions on the RCS. WCAP-14882-P-A describes the input assumptions and code options that are used to simulate non-LOCA transients and accidents for 2-, 3-, and 4-loop reactors designed by Westinghouse including STP, Units 1 and 2.

The methodology for the revised RETRAN-02 input to take credit for the more realistic initial SG water mass as well as for thick metal heat absorption is described in WCAP-14882-S1-P and WCAP-15234-S1-NP (Reference 7) which are referenced by the licensee.

The RETRAN-02 modeling described in WCAP-14882-P-A currently includes modeling of the thick metal structures for events for which it is conservative to release heat from the metal structures into the reactor coolant. This is accomplished by a lumped node technique which maximizes heat transfer into the coolant from the metal structures. For events for which it is conservative to limit the amount of heat transfer from the coolant to the thick metal structures, the current model assumes there is no heat transfer. To take credit for a portion of the heat that is transferred to the metal surfaces, the licensee will use fine mesh detail which will more accurately calculate the amount of heat flow. The NRC staff questioned the adequacy of the noding detail used by the licensee and the heat transfer correlations that will be used. The licensee responded by comparing the results from the RETRAN-02 thick metal model with those calculated by the LOFTRAN code. The thick metal model had previously been approved for use with the LOFTRAN code for Byron Station, Units 1 and 2 and Braidwood Station, Units 1 and 2 (Reference 8). The RETRAN-02 results were found to be in good agreement with those calculated by LOFTRAN. The thick metal heat transfer model in LOFTRAN has been benchmarked against text book data (Reference 9) and found to be conservative. In applying the thick metal model to analyses for STP, Units 1 and 2, the licensee will only utilize a portion of the actual thick metal of the reactor system. In addition, a thermal conductivity of steel will be used which is much less than that of the STP reactor system piping. The NRC staff concludes that the RETRAN-02 thick metal model as described by the licensee is conservative for analysis of LOFW, LOOP, and FWLB events at STP, Units 1 and 2.

The licensee seeks to provide input to the RETRAN-02 code which better represents the initial water mass on the secondary side of the SGs. This is because the homogeneous flow of steam and water assumed in the RETRAN–02 input under-predicts the initial water mass, and is thus conservative. The water in the SGs acts as a heat sink to mitigate the predicted consequences of the LOFW, LOOP, and FWLB events for which the licensee proposes to utilize the revised model. The licensee proposes to utilize a better prediction of SG water mass from NOTRUMP. NOTRUMP SG modeling has previously been used in conjunction with LOFTRAN for FWLB analysis as described in WCAP-9230 (Reference 10). The results were accepted by the NRC staff in the safety evaluations for several operating plants. Instead of assuming homogeneous flow, NOTRUMP utilizes a drift flux model which calculates the individual velocities of steam and water. Since steam generally has a higher velocity than the water within a SG, the resulting water fraction is larger for the same amount of steam flow. Thereby, a greater amount of water is predicted to be in the SG nodes. The drift flux model was derived from data taken at the Westinghouse MB-2 scale model SG test facility. The test facility was designed to model a SG of the feedring type which is the design of the SGs at STP, Units 1 and 2. The total SG water mass predicted by NOTRUMP was compared with that predicted by the Westinghouse SG design codes and found to be acceptable. To provide conservatism in the calculation, the licensee will reduce the SG water masses calculated by NOTRUMP by [ ] before inputting the nodal masses into RETRAN-02. The NRC staff concludes that this approach is acceptable.

To provide a more accurate determination of reactor trip on low SG level, the licensee will determine the SG water mass at the time of reactor trip from the NOTRUMP analysis with allowance for instrument uncertainty and an additional reduction to provide conservative margin. This mass will then be used as the trip parameter in the RETRAN-02 model. The less accurate determination of SG level by RETRAN-02 will therefore not be utilized to determine the time of reactor trip. The NRC staff concludes that this approach is acceptable.

For analysis of events of moderate frequency such as LOOP and LOFW, the licensee will apply the acceptance criteria from the Standard Review Plan and will, in addition, apply a Westinghouse acceptance criterion which requires that complete filling of the pressurizer will not be predicted. This restriction prevents water discharge from the pressurizer safety or relief valves which might cause damage to the valve seats.

Following a FWLB, the rapid reduction of water inventory from the affected SG causes a reduction of heat removal capability, thereby causing reactor system heatup. The RETRAN-02 code generally predicts a more rapid discharge of water from the affected SG than does the NOTRUMP code because in the RETRAN-02 model, the water exiting the SG is assumed to have the same velocity as the steam. The licensee will continue to use the more conservative RETRAN-02 model to predict water loss from the affected SG with the initial water mass determined using NOTRUMP. For analysis of postulated main feedwater line breaks, the licensee will apply the acceptance criteria from the SRP and will, in addition, apply a Westinghouse acceptance criterion which requires that the temperature of the water in the hot legs remains less than the boiling temperature. Meeting this criterion is one way of ensuring that any damage to the core following a FWLB will be minimal.

Based on the supporting information provided by the licensee which demonstrates the conservatism in the models, the NRC staff accepts use of the methodology in WCAP-14882-S1-P and WCAP-15234-S1-NP for analysis of LOOP, LOFW, and FWLB for the STP, Units 1 and 2. The NRC staff review utilized analyses and supporting experimental data supplied by the licensee that are specific to reactor system designs similar to STP, Units 1 and 2. The NRC staff will therefore, require that licensees seeking to apply this methodology for analyses of other nuclear power plants provide supporting justification that use of this methodology is appropriate and conservative for their designs.

4.0 STATE CONSULTATION

In accordance with the Commission's regulations, the Texas State official was notified of the proposed issuance of the amendment. The State official had no comments.

5.0 ENVIRONMENTAL CONSIDERATION

The amendments change a requirement with respect to installation or use of a facility component located within the restricted area as defined in 10 CFR Part 20. The NRC staff has determined that the amendments involve no significant increase in the amounts, and no significant change in the types, of any effluents that may be released offsite, and that there is no significant increase in individual or cumulative occupational radiation exposure. The Commission has previously issued a proposed finding that the amendments involve no significant hazards consideration, and there has been no public comment on such finding published on November 12, 2003 (68 FR 64138). Accordingly, the amendments meet the eligibility criteria for categorical exclusion set forth in 10 CFR 51.22(c)(9). Pursuant to 10 CFR 51.22(b) no environmental impact statement or environmental assessment need be prepared in connection with the issuance of the amendments.

6.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendments will not be inimical to the common defense and security or to the health and safety of the public.

7.0 REFERENCES

1. Letter from T. J. Jordan, South Texas Project Nuclear Operating Company, to U. S. Nuclear Regulatory Commission, "License Amendment Request for Approval of a Change in Analytical Methodology," May 13, 2003, Accession No. ML031400401.

2. Letter from T. J. Jordan, South Texas Project Nuclear Operating Company, to U. S. Nuclear Regulatory Commission, "Request for Additional Information Regarding a License Amendment Request for Approval of a Change in Analytical Methodology," October 6, 2004, Accession No. ML042860042.

3. Letter from T. J. Jordan, South Texas Project Nuclear Operating Company, to U. S. Nuclear Regulatory Commission, "Complete Response to Request for Additional Information Regarding a License Amendment Request for Approval of a Change in Analytical Methodology", November 30, 2004, Accession No. ML043410306.

4. Letter from T. J. Jordan, South Texas Project Nuclear Operating Company, to U. S. Nuclear Regulatory Commission, "Revised Response to Request for Additional Information Question 30 regarding Correlations Used in Computer Codes," January 20, 2005, Accession No. ML050250195.

5. NUREG-0800, Revision 2, "U.S. Nuclear Regulatory Commission Standard Review Plan," July 1981.

6. D. S. Huegel, et. al., "RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analysis," WCAP-14882-P-A, Westinghouse Electric Corporation, April 1999.

7. WCAP-14882-S1-P and WCAP-15234-S1-NP, "RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactors Non-LOCA Safety Analysis Supplement 1-Thick Metal Mass Heat Transfer Model and NOTRUMP-Based Steam Generator Mass Calculation Method," December 2002.

8. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 119 to Facility Operating License No. NPF-37, Amendment No. 119 to Facility Operating Licensee No. NPF-66, Amendment No. 113 to Facility Operating License NO. NPF-72, and Amendment No. 113 to Facility Operating License No. NPF-77 - EXELON Generation Company, LLC - Byron Station Unit Nos. 1 and 2, Braidwood

Station Units Nos. 1 and 2, Docket Nos. STN 50-454, STN 50-455, STN 50-456 and STN 50-457, May 2001, Accession No. ML011420274.

9. P. J. Schneider, "Temperature Response Charts," John Wiley and Sons, Inc., 1963.

10. G. E. Lang, et. al., "Report on the Consequences of a Postulated Main Feedline Rupture," WCAP-9230, Westinghouse Electric Corporation, January 1978.

Principal Contributor: W. Jensen

Date: March 7, 2005

1.0 Introduction / Purpose

The current RETRAN methodology, as described in Reference 1, includes several assumptions that are unnecessarily conservative for the analyses of long-term heatup events, such as Loss of Normal Feedwater (LONF), Loss of Non-Emergency AC Power (LOAC) and Feedwater Line Break (FLB) events.

One unnecessarily conservative assumption is the neglecting of coolant-to-metal heat transfer. This assumption is conservative in that it maximizes primary side coolant temperature changes. However, this level of conservatism is considered unnecessary. Therefore, Westinghouse has developed an enhanced thick-metal model to be used in the RETRAN analysis of selected heat-up events, such as the Loss of Normal Feedwater, Loss of Non-Emergency AC Power and Feedwater Line Break events. The enhanced RETRAN thick-metal model is based on the approved LOFTRAN thick-metal model, documented in WCAP-7907-S1-P (Reference 2). This model is described in detail in Section 2.

Conditions in the current RETRAN steam generator (SG) model are also unnecessarily conservative as the model under-predicts the steam generator mass. Therefore, an existing method in which more realistic but conservative steam generator masses are calculated is employed. This method is based on a detailed, plant-specific steam generator model, generated using the NOTRUMP computer code. This model is described in detail in Section 3.

This report will justify the use of the enhanced thick-metal model and the NOTRUMP based steam generator mass calculations in the analyses of selected heat-up transients, such as the LONF, LOAC and FLB events.

2.0 Enhanced RETRAN Thick-Metal Heat Transfer Model

Heat transfer to and from metal in the reactor coolant system (RCS) is ignored in the majority of the non-LOCA RETRAN analyses (Reference 1). This is conservative in that it minimizes the primary system heat capacity and thus accentuates RCS temperature changes. One exception is in the computation of mass and energy release following a steam line break in which neglecting the heat transfer between the RCS metal and the coolant would be non-conservative. For steam line break mass and energy release calculations performed with RETRAN, Westinghouse applies a simplified thick-metal mass heat transfer model that conservatively over-predicts the heat transfer from the thick-metal to the reactor coolant fluid.

In transients with a relatively large yet slow increase in RCS temperature, such as a loss of normal feedwater event, there would be a substantial amount of heat absorbed in the RCS thick-metal mass. While it is conservative to ignore this effect in heat-up transients, this conservatism is considered unnecessary. To credit the heat absorption characteristics of RCS thick-metal masses, the simplified thick-metal mass heat transfer model used in the steam line break mass and energy release calculations is inappropriate because it would overestimate the heat transfer to the thick-metal.

Therefore, a more enhanced RETRAN thick-metal mass heat transfer model has been developed for use in the long-term heatup events, such as loss of normal feedwater. This model is based on the enhanced LOFTRAN model described in WCAP-7907-S1-P (Reference 2), which was approved by the Nuclear Regulatory Commission (NRC) via the Safety Evaluation Report (SER) of Reference 3 for use in the analysis of feedwater line break. [ ] a,c

[ ] a,c

[ ] a,c

a,c

] It is expected that the net effect of these two differences will effectively be similar in magnitude and not as large as the overall effect of modeling of the thick-metal mass. Therefore, the results from the RETRAN thick-metal model are expected to be comparable to the results from the LOFTRAN thick-metal model for transients with a relatively large yet, slow increase in RCS temperature despite these differences in the methodology. Figure 2-3 and Figure 2-4 compare the pressurizer water volume and [ ] a,c temperature, respectively, in the LOAC event using the enhanced RETRAN thick-metal model to the same parameters obtained when using the previously approved RETRAN model (Reference 1). As in the LOFTRAN thick-metal model, each parameter in the enhanced RETRAN model follows the same trend, just slightly less conservative, as the approved RETRAN model (Reference 1) parameter.

The enhanced RETRAN thick-metal model remains conservative with respect to actual plant conditions in that not all of the coolant-to-metal heat transfer regions are modeled. [a,c

a,c

Figure 2-1:Reactor Coolant System Nodalization

a,c

Figure 2-2:Reactor Pressure Vessel Nodalization

a,c

Figure 2-3:Comparison of Pressurizer Water Volumes for LOAC

a,c

Figure 2-4:Comparison of [ ] Temperatures a,c

3.0 Steam Generator Secondary-Side Mass Calculation Method

3.1 Background

As noted in the US Nuclear Regulatory Commission (NRC) Safety Evaluation Report (SER) for the Westinghouse RETRAN model (see Reference 1), the Westinghouse-developed RETRAN steam generator model conservatively under-predicts secondary-side steam generator water mass. Although low steam generator water masses are conservative for the analyses of many transients, the steam generator masses associated with the Westinghouse-developed RETRAN steam generator models are considered to be overly conservative. As such, Westinghouse has utilized the NOTRUMP steam generator thermal-hydraulic computer code to calculate more realistic but conservative secondary-side steam generator water masses. These masses will be applied in RETRAN analyses of secondary-side transients such as loss of normal feedwater and feedwater line break to define the amount of water mass in the steam generators at the time a low steam generator level reactor trip is reached. Note that the application of these steam generator masses in the RETRAN analyses is similar to the method currently employed in the analyses of secondary-side transients using the LOFTRAN computer code.

3.2 NOTRUMP Code

The NOTRUMP computer code is a one-dimensional nodal network code used for the analysis of thermal-hydraulic transients. Although primarily used for small break LOCA analyses, the NOTRUMP computer code has also been used for steam generator simulations, as presented in WCAP-9230, "Report on the Consequences of a Postulated Main Feedline Rupture" (see Reference 4). This WCAP was submitted to the NRC as the licensing basis for the Westinghouse methodology for analyzing feedwater line break accidents. WCAP-9230 was submitted to the NRC with, and makes reference to, WCAP-9236, "NOTRUMP, A Nodal Transient Steam Generator and General Network Code" (Reference 5), and has since been approved by the NRC on many plant-specific licensing applications as an acceptable methodology for analyzing feedwater line break transients.

a,c

a,c

[ ]

Nodalization of the plant-specific Westinghouse NOTRUMP steam generator model is presented in Figures 3-1 to 3-3, with a description of the fluid node composition provided in Table 3-1. A comparison of the NOTRUMP calculation results to the thermal-hydraulic design code results is presented in Table 3-2.

a,c

Figure 3-1: Secondary-Side Fluid Nodes and Flow Links

a,c

Figure 3-2: Primary-Side Fluid Nodes and Flow Links

a,c

Figure 3-3: Metal Nodes and Heat Links for Primary- and Secondary-Sides

Table 3-1: Fluid Node Composition

a,c

a,c

Table 3-2: Steady-State Model Results Comparison

a,c

3.3 Application of NOTRUMP Masses to RETRAN Calculations

The Westinghouse RETRAN feedring steam generator model, presented in Figure 3.6-2 of WCAP-14882-P-A (Reference 1), is shown in Figure 3-4. [ ]a,c

The NOTRUMP and RETRAN steam generator transient responses of key steam generator parameters on both the primary-side and secondary-side, including secondary-side mass, to a loss of feedwater event are compared in Figures 3-5 to 3-10.

a,c

Figure 3-4: Westinghouse RETRAN Feedring Steam Generator Nodalization

a,c

Figure 3-5: Primary-Side Mass Flow Rate for LOAC

a,c

Figure 3-6: Primary-Side Pressure for LOAC

a,c

Figure 3-7: Primary-Side Enthalpy for LOAC

a,c

Figure 3-8: Secondary-Side Feedwater Mass Flow Rate for LOAC

a,c

Figure 3-9: Secondary-Side Steam Mass Flow Rate for LOAC

a,c

Figure 3-10: Secondary-Side Total SG Mass for LOAC

4.0 Conclusions

An enhanced RETRAN thick-metal model and detailed NOTRUMP-based steam generator mass calculation method have been developed for use in the RETRAN analyses of selected heat-up transients, such as the Loss of Normal Feedwater, Loss of Non-Emergency AC Power and Feedwater Line Break events. In each case, unnecessary conservatisms (i.e., the models are more realistic) have been removed in the assumptions used in the current RETRAN methodology for the analysis of these long-term heat-up events, as described in Reference 1.

The enhanced RETRAN thick-metal model was developed to credit energy absorbed by the RCS piping due to coolant-to-metal heat transfer. The enhanced RETRAN thick-metal model is described and justified in Section 2 for use in long-term heat-up events. As described in Section 2, the model is more realistic than current methodology, yet conservative as not all components of the RCS are modeled as thick-metal.

The use of a more detailed, steam generator model in the RETRAN analyses of long-term heat-up events is described and justified in Section 3. The steam generator model utilizes the NOTRUMP computer code to calculate more realistic but conservative steam generator masses.

5.0 References

1. WCAP-14882-P-A (Proprietary) and WCAP-15234-A (Non-Proprietary), "RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analyses," April 1999.

2. WCAP-7907-S1-P, Revision 1 (Proprietary) and WCAP-7907-S1-NP, Revision 1 (Non-Proprietary) "LOFTRAN Code Description Supplement 1 – LOFTRAN Thick Metal Mass Heat Transfer Models," January 2001.

3. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 119 to Facility Operating License No. NPF-37, Amendment No. 119 to Facility Operating License No. NPF-66, Amendment No. 113 to Facility Operating License No. NPF-72, and Amendment No. 113 to Facility Operating License No. NPF-77 – EXELON Generation Company, LLC – Byron Station Unit Nos. 1 and 2, Braidwood Station Unit Nos. 1 and 2, Docket Nos. STN 50-454, STN 50-455, STN 50-456 and STN 50-457.

4. WCAP-9230, "Report on the Consequences of a Postulated Main Feedline Rupture," G. E. Lang and J. P. Cunningham, January 1978.

5. WCAP-9236, "NOTRUMP, A Nodal Transient Steam Generator and General Network Code," P. E. Meyer and G. K. Frick, February 1978.

NRC Requests for Additional Information (RAIs) with Westinghouse Responses

1. The licensee states that the proposed analytical methods will be used for analyses of long-term heatup events such as Loss of Normal Feedwater, Loss of Offsite Power, and Feedwater Line Break events. Please list all of the transient and accident analyses for which the proposed RETRAN thick metal mass heat transfer model and NOTRUMP-based steam generator mass calculation methods will be applied.

Response:

The proposed RETRAN thick metal mass heat transfer model and NOTRUMP - based steam generator mass calculation methods will only be applied to the analyses of long term heatup events listed in the WCAP. These events are the Loss of Normal Feedwater, Loss of Offsite Power, and Feedwater Line Break events.

2. WCAP-14882-S1-P, "RETRAN-02 Modeling and Qualification For Westinghouse Pressurized Water Reactors Non-LOCA Safety Analyses, Supplement 1 - Thick Metal Mass Heat Transfer Model and NOTRUMP-Based Steam Generator Mass Calculation Method," Revision 0, provides the technical basis for the proposed analytical methods. This WCAP provides discussions and analyses which are generic. Please justify the application of these methodologies for South Texas Units 1 and 2. Are there any restrictions or limitations associated with the application of these proposed analytical methods for South Texas Units 1 and 2?

Response:

The thick metal model discussed in WCAP-14882-S1-P uses the generic nodalization model for the Reactor Coolant System (RCS) discussed in WCAP-14882-P-A and applied to a wide range of plants, including Westinghouse designed 2-loop, 3-loop and 4-loop plants, Framatome-designed 3-loop plants and adapted for CE-designed plants. Given that the approved RCS nodalization was used and given that a limited number of RCS nodes were credited in the thick metal model, the model is an acceptable model to be used in the South Texas Unit 1 and 2 safety analyses. The nodalization from WCAP-14882-P-A has been used consistently in the safety analyses, however future models may subdivide the hot leg into a 3-node arrangement to allow for more accurate interaction with the pressurizer. In the case that a 3-node hot leg would be used with the thick metal model discussed in WCAP-14882-S1-P, the hot leg metal masses would be appropriately distributed across the three nodes. Restrictions and limitations associated with the application of the thick metal model are those identified in WCAP-14882-P-A and to those accidents identified in the response to question #1.

3. Various versions of the RETRAN code have been reviewed and approved by the NRC staff. The staff generic safety evaluation reports (SERs) and technical evaluation reports (TERs) for the various RETRAN versions include a number of limitations, restrictions and items identified as requiring additional user justification regarding the use of RETRAN. As part of the staff's review of the Westinghouse RETRAN model (WCAP-14882-P-A), Westinghouse addressed these items through RAI responses which are documented in Appendix B of WCAP-14882-P-A. Do the proposed analytical modeling changes invalidate any of the responses to the RETRAN limitations, restrictions and items identified as requiring additional user justification in Appendix B of WCAP-14882-P-A?

Response:

No. As part of the creation of the thick metal model as discussed in WCAP-14882-S1-P, the RETRAN limitations, restrictions, and items identified requiring user justification in Appendix B were examined. This included such things as performing time step sensitivities, heat transfer coefficients sensitivities, etc., to ensure that the model is conservative in its application to the heatup transients previously identified. Again, for conservatism, a limited number of RCS nodes/RCS sections were considered.

Thick-Metal Mass Heat Transfer Model

4. Section 2.0 of WCAP-14882-S1-P, Revision 0, states that the simplified thick-metal mass heat transfer model used in the steam line break mass and energy release calculations would overestimate the heat transfer to the thick-metal and is inappropriate for use in the proposed application. Please discuss how the simplified thick-metal heat transfer model is different from the thick-metal mass model to be used in the heatup event calculations.

Response:

The primary difference is in the sub-nodalization applied to the metal lumps in the thick metal model. In the case of the steam line break mass and energy release calculations the intent is to maximize the primary RCS heatup to thereby maximize the secondary side mass and energy release. Therefore, one node is assumed for each metal lump, which acts to rapidly transfer the energy in the thick metal masses to the RCS coolant. Conversely, since the intent of the thick metal model discussed in WCAP-14882-S1-P is to credit the thick metal masses to retard the heatup of the primary coolant, each thick metal node has sub-nodes such that the heat transfer from the coolant to the thick metal is conservatively minimized. In both instances, the model used is conservative in its intended application. The details of the thick metal model are presented in the approved LOFTRAN Thick Metal Mass Heat Transfer Models report (WCAP-7907-S1-P), which is referenced in WCAP-14882-S1-P.

5. Please discuss how the thick-metal mass heat transfer model is incorporated into RETRAN. Is any information written into the source code (hard-wired into the code) or is all information entered via user input options? Provide a listing and descriptions of the RETRAN input parameters needed to implement the thick-metal mass heat transfer model and discuss how any numerical values are calculated. Is this work performed under a quality assurance program?

Response:

The thick metal mass heat transfer model is incorporated into RETRAN via the input deck only. A sample RETRAN input listing of the thick metal mass model is provided separately. There are no changes made to the RETRAN source code to support the thick metal mass heat transfer model. As shown by the RETRAN input listing, the thick metal mass heat transfer model is composed of heat conductor cards (defined by the 15XXXY cards) and the heat conductor geometry cards (17XXYY cards). There are a total of [ ] [a,c] heat conductor cards; [ ] [a,c] identified with the hashed marking in Figures 2-1 and 2-2 of Supplement 1 to WCAP-14882. In addition, there are a total of [ ] [a,c] heat conductor geometry cards, each one modeling the thick metal masses as a [ ] [a,c]. Tables 5-1 and 5-2 shown below discusses each of the inputs for these two sets of RETRAN input cards.

Table 5-1
Information for the Heat Conductor (15XXXY) Cards

a,c

Table 5-2
Information for the Heat Conductor Geometry (17XXYY) Cards [a,c]

The values chosen for the inputs on the 15XXXY and 17XXYY cards are based on sensitivity runs that examined various inputs, such as [ ] [a,c], to ensure that the overall model was conservative for its intended application. In addition to ensuring that the model was conservative, it was purposely decided to credit only a portion of the thick metal masses. Thick metal masses associated with the [ ] [a,c] for conservatism.

Finally, the analyses performed in support of the information presented in Supplement 1 to WCAP-14882 were performed under the NRC-approved Westinghouse Quality Management System.

6. Heat transfer from the coolant to the RCS metal mass is modeled using the [ ]^{a,c} Please justify the application of the [ ]^{a,c} for each of the [ ]^{a,c} RCS metal mass regions included in the thick-metal mass heat transfer model and listed in Section 2.0 of WCAP-14882-S1-P, Revision 0.

Response:

RETRAN automatically applies an appropriate heat transfer correlation as warranted by the analysis conditions (e.g., at relatively high Reynold's numbers the [ ]^{a,c} correlation is used and at low Reynold's numbers the [ ]^{a,c} correlation is used). A review of the cases with natural circulation identified that RETRAN used the [ ]^{a,c} for all the regions. Additionally, the overall model is conservative in that only a portion of the RCS is modeled.

7. Heat transfer from the coolant to the RCS metal mass is modeled using the [ ]^{a,c} The form of this equation used in the LOFTRAN thick-metal mass heat transfer model (WCAP-7907-S1-P, Revision 1) applies an [ ]^{a,c}

Response:

The RETRAN computer code, as approved by the NRC, is programmed with the [ ]^{a,c} and therefore, does not alter the calculation based on the direction of the energy flow. This is considered to be acceptable based on the following discussion.

The RETRAN thick metal mass heat transfer model was compared to the LOFTRAN model, which was extensively tested against the information presented in *Temperature Response Charts*, Dr. P.J. Schneider, 1963 John Wiley & Sons, Inc. In this reference, numerous charts are presented that reflect increases/decreases in the metal temperature due to an increase/decrease in the fluid temperature for various metals, fluids, and geometries. For the purposes of benchmarking the LOFTRAN thick metal mass heat transfer model, charts were selected from the above reference for the situation where water with an increasing temperature passes through metal piping and the temperature of the piping changes accordingly. Based on a comparison of the LOFTRAN thick metal model to the chart data for the situation where [

] a,c This is considered to be acceptable and conservative for the application of this thick metal model in transients for which it is conservative to [ ] a,c

In addition, as was noted in the response to RAI #5, it was purposely decided to credit only a portion of the thick metal masses. Thick metal masses associated with the [

] a,c for conservatism.

The results generated by the RETRAN thick metal mass model were in good agreement with the LOFTRAN results. Therefore, based upon the good agreement between the LOFTRAN/RETRAN models and given the fact that a large portion of the thick metal masses are ignored for conservatism, the thick metal model is considered to be acceptable for use in the licensing basis Loss of Normal Feedwater and Feedline Break transients.

8. Section 2.0 of WCAP-14882-S1-P, Revision 0, states that the RETRAN thick-metal mass heat transfer model includes [ ] a,c RCS regions, with the metal mass associated with each region [ ] a,c The LOFTRAN thick-metal mass heat transfer model (WCAP-7907-S1-P, Revision 1) incorporates the same RCS regions, but each region can contain [ ] a,c

   a. Please clarify the definition of node and subnode as used in the RETRAN topical report WCAP-14882-S1-P, Revision 0. Are they consistent with the terms metal sections and lumps as used in the LOFTRAN topical report WCAP-7907-S1-P, Revision 1?

   Response:

   The conductor model in the RETRAN code is described in the RETRAN Theory Manuals (see Reference R8 below). In the RETRAN code, [

   ] a,c To more clearly show the relationship of the RETRAN noding versus the LOFTRAN noding the following table is presented.

Table 8-1
Comparison of the RETRAN versus LOFTRAN Noding Terminology

RETRAN terms	LOFTRAN terms	Discussion
Conductor	Section	Metal with given geometry in thermal contact with water
Nodes (Regions)	Lumps	Sequential layers of the above metal. Each layer may be defined as a different material. Each LOFTRAN lump has an average temperature defined.
Space Steps or "meshes" (Subnodes)	N/A	[RETRAN only] Smaller divisions of a given layer described above. These divisions are sublayers of the same material, but each subnode has its own temperature.

Reference R8: J. H. McFadden, et. al., "RETRAN-02 --- A Program for Transient-Hydraulic Analysis of Complex Fluid Flow Systems," EPRI NP-1850-CCMA.

b. Please discuss the sensitivity studies performed to determine that this noding configuration option for the RETRAN model are acceptable.

Response:

The RCS nodalizations illustrated in Figure 2-1 and Figure 2-2 of Supplement 1 to WCAP-14882-P-A are identical to those documented in WCAP-14882-P-A. The RCS volumes in contact with the thick-metal conductors are consistent with the regions in which thick-metal heat transfer was assumed in the LOFTRAN enhanced thick metal model, as documented in WCAP-7907-S1-P. As discussed in the response to RAI #7, the LOFTRAN thick metal mass heat transfer model was extensively tested against the information from the *Temperature Response Charts*. Therefore, the LOFTRAN results were used to benchmark the RETRAN model. In performing the benchmark, the RETRAN nodes were made identical to the LOFTRAN lumps in terms of geometry and material properties. Then the required number of subnodes was determined by increasing the number of subnodes used in each node until a good match was obtained. RETRAN sensitivities were also performed to demonstrate that modeling the nodes as [ ]^{a,c} Additionally, sensitivities were performed on the material used to model the thick metal masses. The results of these sensitivities demonstrated that modeling the nodes as [ ]^{a,c} was more conservative when compared to modeling the heat transfer characteristics of [ ]^{a,c}

c. As described in the LOFTRAN topical report WCAP-7907-S1-P, each metal section can be modeled as [

] a,c Please describe the geometric configurations available in the RETRAN model.

Response:

The geometric configurations available in the RETRAN model include a [

] a,c

d. Please discuss the approach used to determine which geometry should be applied to a particular metal section, the number of metal sections which should be modeled in each region, and the number of lumps to use in each metal section.

Response:

Sensitivities showed that the geometry chosen for a particular metal section is not critical to the results. However, the results can be sensitive to the number of subnodes modeled for each node. Sensitivities were performed to ensure that a sufficient level of detail (that is, nodalization) was assumed to demonstrate that accurate results were being obtained by comparing the RETRAN results to the LOFTRAN results (see response to 8.b.).

e. Please provide the South Texas specific input deck for the RETRAN thick-metal mass heat transfer model. The information requested in RAI 5 above will be used to interpret this model input.

Response:

A complete RETRAN input deck is provided separately.

9. In the RETRAN thick-metal mass heat transfer model, [

] a,c Please provide a discussion of the sensitivity studies performed and the results obtained which justify the use of all [ ] a,c materials.

Response:

Sensitivities have indicated an insignificant difference in the results.

10. Section 2.0 of WCAP-14882-S1-P, Revision 0, states that the RETRAN thick-metal mass heat transfer model uses material properties (e.g., density, thermal conductivity, specific heat capacity) that vary with temperature, whereas the LOFTRAN thick-metal mass heat transfer model (WCAP-7907-S1-P, Revision 1) incorporates [ ] a,c of the metal. Please provide a table of the material property values as a function of temperature, and discuss how these values are incorporated into the RETRAN thick-metal mass heat transfer model. Include a reference for the material property values.

Response:

The thick-metal mass material properties are provided below in Table 10-1 and Table 10-2. The material properties were taken from an internal Westinghouse Properties Manual. In the RETRAN thick metal mass model input deck, the thick-metal mass thermal conductivity properties (Table 10-1) are provided by the RETRAN input cards 18070X (where x = 0, 1, 2 and 3) and the thick-metal mass volumetric heat capacity properties (Table 10-2) are provided by the RETRAN input cards 19070X (where x = 0, 1, 2 and 3). These user input lookup tables are used by RETRAN for defining the thick-metal mass material properties.

Table 10-1
Thermal Conductivity for [ ] a,c

Temperature (°F)	Thermal Conductivity (Btu/ft-hr-°F)

a,c

Table 10-2
Volumetric Heat Capacity for [ ] a,c

Temperature (°F)	Volumetric Heat Capacity (Btu/°F - ft^3)

a,c

11. Section 3.3 of the LOFTRAN thick-metal mass heat transfer model topical report (WCAP-7907-S1-P, Revision 1) discusses the initialization calculations performed for the LOFTRAN thick-metal mass heat transfer model. Please provide a discussion of the initialization assumptions and calculations performed for the RETRAN thick-metal mass heat transfer model.

Response:

The fluid temperature of the volume in contact with the conductor (i.e., metal) is used to define the steady-state conditions of the thick metal mass.

12. At some point in the calculation, the RCS metal mass could "saturate" such that no further energy can be transferred to the metal. Please discuss how this situation is accounted for in the RETRAN thick-metal mass heat transfer model.

Response:

When the RCS metal mass temperature approaches the temperature of the RCS fluid at that corresponding location, the heat transfer to the metal mass is reduced. When the conditions are such that the RCS metal mass "saturates" no additional heat is transferred to the metal mass.

13. Please discuss how the RETRAN thick-metal mass heat transfer model accounts for a feedwater line break that involves two-phase discharge. Include a discussion of the impacts on the results of interest for this type of break including RCS pressure, Pressurizer water level and DNBR.

Response:

Heat transfer to the thick metal mass only occurs on the primary and the primary conditions are currently limited to subcooled conditions. Likewise for the "other" heatup events analyzed, there is no two phase flow in the primary system throughout the events. Therefore, there is nothing specific to the Feedline Break event that would affect the thick-metal mass model.

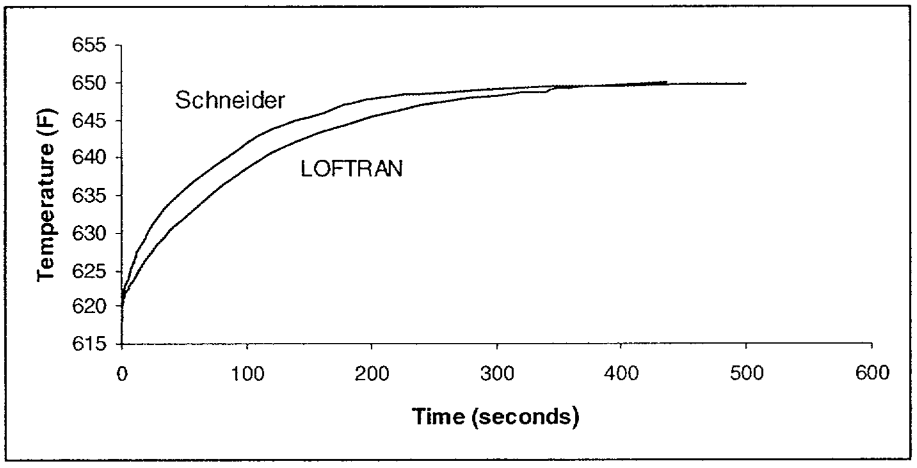
14. WCAP-14882-S1-P, Revision 0 provides the technical basis for the proposed RETRAN thick-metal mass heat transfer model. This topical report does not provide any information regarding verification or validation of the proposed RETRAN thick-metal mass heat transfer model. Please provide a discussion of the work performed to verify that the model performs as expected and that the amount of energy transferred to and absorbed by the RCS metal is accurate and realistic. Include results of any

comparisons made to test data or other benchmarking, and demonstrate that the RETRAN thick-metal mass heat transfer model is not overestimating heat transfer to the RCS metal.

Response:

As discussed in the response to RAI #5, Westinghouse performed extensive comparisons of the LOFTRAN thick metal model to the expected response. A comparison of the LOFTRAN thick metal model results for the steam generator inlet metal section to what would be expected based on the data obtained from *Temperature Response Charts*, Dr. P.J. Schneider, 1963 John Wiley & Sons, Inc. was performed for an increase in temperature from 618°F to 650°F. As can be seen in Figure 14-1, the LOFTRAN thick metal model response to an increase in the fluid temperature results in a very similar increase in the metal mass temperature, with the LOFTRAN results being slightly conservative. This conservative response, in addition to the fact that a large portion of the RCS thick metal masses are completely ignored, ensures that the thick metal model is conservatism for use in heatup transients.

Figure 14-1 Comparison of the LOFTRAN Thick Metal Model to the Schneider Predicted Results



15. The RETRAN thick-metal mass heat transfer model accounts for convection and conduction heat transfer. Other heat transfer mechanisms exist (radiation heat transfer) that could influence the energy transferred to the RCS metal and the RCS metal temperatures. Please discuss how any other heat transfer mechanisms impact the results of the RETRAN thick-metal mass heat transfer model.

Response:

Radiation heat transfer is not modeled since the effect would be small in comparison to the energy lost to the containment atmosphere.

The effect of heat losses from the RCS to the containment environment is conservatively ignored in the non-LOCA analyses.

16. Are heat losses from the pressurizer modeled as part of the RETRAN thick-metal mass heat transfer model? Modeling these heat losses would be non-conservative for the heatup events for which the thick-metal mass heat transfer model is being applied. If such losses are modeled and credited, please quantify the conservatism associated with this approach.

Response:

[ ][a,c]

NOTRUMP-Based Steam Generator Mass Calculation Method

17. The licensee states that WCAP-9230 was submitted to the NRC along with, and makes reference to, WCAP-9236, and has since been accepted by the NRC as an approved methodology for analyzing feedwater line break transients on many plant-specific licensing applications. Please provide a reference to a similar license amendment request where this methodology has been accepted by the staff. This would assist the staff in its review.

Response:

As an example, the Vogtle plant FSAR presents the analysis of the Feedwater System Pipe Break and references WCAP-9230 on page 15.2.8-8. The NRC's position regarding the application of the WCAP-9230 Feedwater System Pipe Break methodology to the Vogtle plant is noted in Section 15.2.8 Feedwater System Pipe Breaks of NUREG-1137, *Safety Evaluation Report Related to the Operation of Vogtle Electric Generating Plant, Units 1 and 2.*

> "Sensitivity studies, as presented in WCAP-9230, "Report on the Consequences of a Postulated Main Feedline Rupture," have shown that the most limiting feedwater line break is a double-ended rupture of the largest feedwater line. The staff is reviewing WCAP-9230. Staff review at this time indicates reasonable assurance that the conclusions of the Westinghouse submittal will not be appreciably changed by completion of the review. If the final results of the review indicate that revisions to the applicant's analyses are necessary, the applicant will be required to implement the results of such changes. The staff does not consider this an open item."

18. Both the licensees' submittal and WCAP-14882-S1-P, Revision 0 reference WCAP-9236, "NOTRUMP, A Nodal Transient Steam Generator and General Network Code," dated February 1978. NOTRUMP was reviewed and approved by the staff in 1985 under WCAP-10079-P-A, "NOTRUMP, A Nodal Transient Small Break and General Network Code." Why is WCAP-9236 referenced rather than the approved WCAP-10079-P-A?

Response:

Westinghouse agrees that it is probably more appropriate to reference both NOTRUMP WCAPs since the WCAP-10079-P-A refers to the more recent version of the NOTRUMP computer code. The primary reasons that WCAP-10079-P-A was not mentioned include 1) it was not referenced in the Feedline Break topical (WCAP-9230) and 2) WCAP-10079-P-A was written for the application of the NOTRUMP computer code to small break Loss of Coolant Accidents. The SER for WCAP-10079-P-A specifically states the following:

> "This SER documents the staff review of the NOTRUMP computer code program for calculating small break loss of coolant accidents (LOCA). Our review concludes that NOTRUMP is acceptable for calculating small break LOCA events."

The responses to RAIs 17 and 19 provide additional information concerning the use of the NOTRUMP code for performing Feedline Break transients.

19. Section 3.1 of WCAP-14882-S1-P, Revision 0, states that the application of the steam generator masses in the RETRAN analysis is similar to the method currently employed in the analyses of secondary-side transients using the LOFTRAN computer code. Please provide a reference to the staff approval of the application of this methodology using LOFTRAN.

Response:

The application of the NOTRUMP code for defining steam generator masses in the LOFTRAN computer code is noted on page 4-2 of WCAP-9230.

> "The heat transfer area is reduced as a function of secondary water inventory as verified using the NOTRUMP simulation."

Also, as shown on Figure 4-2 of WCAP-9230, the NOTRUMP code provides the data that can be used to verify the SG level trip and heat transfer models in the LOFTRAN computer code. The water level trip is modeled in the LOFTRAN code as a secondary side water inventory since the LOFTRAN code does not have a detailed indicated narrow range water level model. The reference for the NRC acceptance of the application of the WCAP-9230 methodology using the LOFTRAN computer code is noted in the response to RAI #17.

20. Section 3.1 of WCAP-14882-S1-P, Revision 0, states that using the NOTRUMP code will result in more realistic but conservative secondary side steam generator water masses. Please discuss how this methodology remains conservative.

Response:

As noted in Section 3.1 of WCAP-14882-S1-P, the NOTRUMP code is used to provide a more realistic estimate of the amount of mass in the steam generator at the low-low steam generator water level reactor trip setpoint. Since there is some uncertainty as to what the actual mass is, the predicted NOTRUMP mass at the reactor trip setpoint is [ ]^{a,c} before it is used in the LOFTRAN or RETRAN computer codes. This [ ]^{a,c} primarily accounts for any uncertainty in the drift-flux model, which can affect the NOTRUMP calculated mass. Conservatisms also exist in the use of the low-low steam generator water level reactor trip assumption, which accounts for the instrumentation uncertainties associated with the reactor trip function. The typical assumption for the safety analysis value for the low-low steam generator water level setpoint for the Feedline Break event is 0% of narrow range span (a higher value may be used for transients such as the Loss of Normal Feedwater since no adverse environmental errors are present). This accounts for a number of uncertainties associated with the setpoint, for example, adverse environmental errors (for Feedline Break), the process measurement term, and reference leg heatup uncertainties. Based on these conservatisms, the mass value used in the RETRAN safety analyses are considered to be sufficiently conservative.

21. Please discuss how the following elements are addressed in the NOTRUMP-Based Steam Generator Mass Calculation Method:

    a. Heat transfer between the primary and the secondary side once the steam generator tubes begin to uncover.

    Response:

    The NOTRUMP based steam generator mass calculations are used to define the mass in the steam generators at the time of reactor trip which is well before steam generator tube bundle uncovery occurs. In the RETRAN model, when the steam generator tubes are uncovered, the heat transfer from the primary to the secondary degrades.

    b. Steam superheating once the steam generator tubes begin to uncover.

    Response:

    Again, this is beyond the point where the NOTRUMP-based steam generator mass calculations are used.

c. Steam generator secondary side water level/inventory calculation after the low water level trip is reached.

Response:

The water level indication is not tracked following receipt of the low water level trip. The mass inventory is strictly a mass balance calculation.

d. Feedwater line break discharge quality and the associated impact on the transient.

Response:

The feedwater line discharge quality calculated by RETRAN is nearly identical to NOTRUMP before the feedring uncovers. Following feedring uncovery and reactor trip, the RETRAN-calculated discharge quality is more conservative than NOTRUMP since the RETRAN-calculated discharge quality is lower. This maximizes the mass discharge out of the break and thereby maximizes the RCS heatup.

22. Figures 3-1 to 3-3 of WCAP-14882-S1-P, Revision 0 illustrate the nodalization of the plant-specific Westinghouse NOTRUMP steam generator model, and Table 3-1 provides a description of the fluid node composition. Was this steam generator model previously reviewed and approved by the staff as part of the NOTRUMP model review? Also, please discuss any plant-specific changes incorporated for application of the model to South Texas Units 1 and 2.

Response:

The nodalization of the plant-specific Westinghouse NOTRUMP steam generator model as presented in Figures 3-1 through 3-3 of WCAP-14882-S1-P, Revision 0 is based on providing an equivalent arrangement as the NOTRUMP steam generator nodalization identified in Appendix B of WCAP-9230. As far as any plant-specific changes, the biggest difference is the location of the feedwater inlet. The steam generator presented in Appendix B of WCAP-9230 is a pre-heat steam generator which injects feedwater at the bottom of the steam generator. Baffles located in the bottom of the steam generator direct the flow across the steam generator tubes on the cross-over leg (cold-leg) side of the steam generator tubes. The water then passes up through the remainder of steam generator tubes. The steam generator presented in Supplement 1 of WCAP-14882 is a feedring steam generator which injects feedwater near the top of the downcomer of the steam generator. The feedwater then travels down the downcomer before it travels up through the steam generator tubes. The other major difference is the increased number of nodes modeled in the steam generator presented in Supplement 1 of WCAP-14882 versus the steam generator model presented in WCAP-9230. This is primarily due to the greater computer speeds available which allow for greater nodalization to be applied when performing computer modeling of systems. Finally, the steam generator model used for the South Texas Unit 1 and 2 plants incorporates the plant specific volumes, elevations, flow areas, flow rates, steam pressures, etc.

23. Section 3.2 of WCAP-14882-S1-P, Revision 0, states that the plant-specific NOTRUMP steam generator model has been benchmarked against a Westinghouse thermal-hydraulic steam generator steady-state performance code, which has been extensively compared to actual plant data. Please provide the name of this code, and discuss the types of actual plant data used for the comparisons. Also, discuss the NOTRUMP steam generator model performance and comparisons to any available plant data under transient conditions.

Response:

The steam generator steady-state performance code is the GENF computer code which has been used by Westinghouse for years to define steam generator design and performance characteristics. The types of actual plant/test data that the code has been compared against includes [

] a,c as well as ensuring that both primary and secondary side volumes/dimensions are verified.

24. Table 3.2 of WCAP-14882-S1-P, Revision 0, provides a comparison of the NOTRUMP model results with a Westinghouse thermal-hydraulic steam generator steady-state performance code. The comparisons are made for key system parameters for one steady state data point only, and certainly the differences between the two codes are small. Please provide similar comparisons which cover the expected range of application of the NOTRUMP code for the purpose described in this License Amendment Request. Also, please provide the technical basis for acceptance of the calculated differences between the two codes.

Response:

The Westinghouse thermal-hydraulic steam generator steady-state performance code is used to define the boundary conditions for the NOTRUMP computer code. The steady-state performance code has been used for many years by Westinghouse to accurately predict steam generator performance characteristics associated with power upratings, increases in steam generator tube plugging levels, reductions in RCS flows, etc. The code has been verified and validated against actual plant/test data and has been shown to accurately predict the steam generator behavior, such as the steam pressure and circulation ratio. Boundary conditions, as defined by this steady-state performance code (not shown in Table 3-2 but used as input to the NOTRUMP code) include the primary side pressure, RCS flow rate and steam generator inlet enthalpy and secondary side conditions, such as the feedwater enthalpy and the steam/feedwater flow rate. Using these boundary conditions, the NOTRUMP model was created and initialized. A comparison of the steady-state performance code results to the NOTRUMP code results is presented in Table 3-2 for those parameters that are not input. As shown by this comparison there is good agreement between the two codes.

The technical basis for the small differences in the results comparison shown in Table 3-2 are justified primarily by the fact that, for conservatism and due to potential uncertainty in the drift-flux model, the resulting NOTRUMP-calculated mass is [ ]^{a,c}. This [ ]^{a,c} is specified by the Westinghouse methodology for analyzing long-term heat removal transients, that is, the Loss of Normal Feedwater and Feedline Break events. In addition, many other conservatisms exist in both the Loss of Normal Feedwater and Feedline Break analyses, including the application of uncertainties on the initial power, RCS Tavg and pressure, and assuming a low-low steam generator water level trip minus the worst uncertainties. The Westinghouse methodology does not credit any of the control systems to mitigate the consequences of the event. Further, the analysis methodology assumes minimum conservative auxiliary feedwater flows. This maximizes the long-term heatup effects. Westinghouse also applies a very restrictive requirement of not filling the pressurizer for the Loss of Normal Feedwater event and the no-hot-leg-boiling criterion for the Feedline Break event, as described in WCAP-9230, to ensure that the core remains covered with water and maintains a coolable geometry.

When compared to a Loss of Normal Feedwater event at a plant, the analysis is very conservative. Based on operating experience, a loss of feedwater event at a plant is typically a cooldown concern due to the operation of the control systems, including the steam dumps (which are not credited in the safety analyses) and the initiation of all the auxiliary feedwater pumps. Therefore, given the conservatisms in the analyses and based on an understanding of the extreme difference in the results of an actual transient at the plant versus what the analyses predict, the safety analyses, including the use of the NOTRUMP code, remain bounding even considering the application of the thick metal masses.

Concerning the expected range of application of the NOTRUMP code, the primary purpose of running the NOTRUMP code is to determine the steam generator trip mass associated with the low-low steam generator water level reactor trip setpoint while at full power steam flow conditions. The limiting heatup events that utilize the NOTRUMP trip mass are the Loss of Normal Feedwater and the Feedline Break events which are analyzed at full power conditions with uncertainties applied to the initial conditions and to the low-low steam generator water level trip setpoint. It is at full power conditions where the behavior and the thermal hydraulic characteristics of the steam generator are important to the transient. Extensive work has been performed to demonstrate that the models applied in the NOTRUMP code, and in particular the drift flux model, are accurately predicting steam generator behavior. This is discussed further in the response to RAI #29.

25. Section 3.3 of WCAP-14882-S1-P, Revision 0, discusses the method used to calculate and apply the NOTRUMP steam generator masses to RETRAN. Initially, the RETRAN steam generator mass is initialized [

]^{a,c}

a. Please discuss the use of computational time steps for this methodology and how transient time differences between the two computer codes are accounted for.

Response:

It should be noted that since the codes are not linked, differences in time steps are not significant. The important consideration is that the computational time step size used in each of the codes is sufficiently small to ensure that the codes are predicting reasonably accurate results. The RETRAN code uses a Courant limit which limits the volume mass transport with respect to the total mass. In effect, the time step must be smaller than the time interval required for the fluid to traverse any control volume. Likewise, the NOTRUMP code has a similar type of time step selection to ensure that the time size is not too large for the condition being analyzed. Given that both codes have internally adjusted time step calculations, a one-for-one comparison of the time step size is not meaningful. The transient conditions generated with RETRAN were input to the NOTRUMP code via arrays of the boundary conditions (that is, primary and secondary-side temperature, pressure and flow). NOTRUMP performs a linear interpolation of the data. Given that the RETRAN time steps are relatively small and the response of the important transient conditions are smooth, it is concluded that this is a reasonable approach for modeling the transient.

b. Figure 3-10 provides a plot of total steam generator mass, and shows a linear decrease over time. Are the NOTRUMP steam generator masses calculated at only two state points (initial conditions and low-low level reactor trip setpoint)? If so, please justify any assumptions on steam generator mass for times between these two state points, and for times after the reactor trip.

Response:

The NOTRUMP steam generator masses are calculated throughout the transient. The plot shows a linear response since the normal feedwater flow is terminated for the Loss of AC Power transient and the steam generator mass drops at a constant rate as steam continues to the turbine (see Figure 3-9 for the secondary-side steam mass flow rate) which remains constant until a turbine trip occurs.

c. Please discuss how the NOTRUMP steam generator masses (liquid, steam and total) are input to the RETRAN model. Please provide a sample of the RETRAN input.

Response:

The NOTRUMP steam generator mass at the reactor trip condition is input with a RETRAN trip card. This mass corresponds to [ ] a,c of the NOTRUMP steam generator mass for a given low-low steam generator water level trip setpoint. When the total mass in the RETRAN model reaches a condition that equals the input steam generator trip mass, a reactor trip is generated. It should be noted that individual liquid and steam masses are not used as input, that is, it is only the total mass that is used.

The RETRAN trip card associated with this modeling approach is shown in the example below where [ ] a,c is the assumed trip mass and -959 defines the control block calculation for the transient total mass in the steam generator. When the transient mass reaches [ ] a,c in any one steam generator, a reactor trip signal is generated.

The example RETRAN trip card is:

44060 40 -14 -959 0 [ ] a,c 2.00 * Low SG Trip Mass

d. The report states that the [ ] a,c in the RETRAN steam generator model could be used as an alternative method for increasing the mass on the secondary side of the steam generator. Please discuss how this would be accomplished and the modeling changes necessary to implement this method. Would the expected results be the same as for [ ] a,c

Response:

[

]^{a,c}

e. Figures 3-5 to 3-10 are labeled as being for a LOAC event. The text of Section 3.3 states that these figures are for a loss of feedwater event. Please clarify.

Response:

The case analyzed and presented in WCAP-14882-S1 is the Loss of Normal Feedwater without offsite power available.

f. Please discuss the significance of the [ ]^{a,c} Why is this different from the NOTRUMP results?

Response:

The very slight [ ]^{a,c} as calculated by RETRAN is caused by inertial effects in the feedwater line as the feedwater is terminated using a step change. Due to the inertia of the flow in the feedwater line, the pressure in the feedwater line following the termination of feedwater drops relative to the pressure just inside the steam generator, thereby causing the [ ]^{a,c}

g. Please discuss the modeling changes made to the RETRAN steam generator level trip function to compensate for changes in the steam generator volume / mass, and to allow this trip function to activate on mass rather than level. Discuss how these changes are verified to be functioning properly.

Response:

There were no "adjustments" made to the level trip function to compensate for changes in the steam generator volume / mass, rather, the SG volume was increased so the resulting initial SG mass matched the NOTRUMP initial mass. The trip cards were modified to trip on steam generator total mass versus on the indicated steam generator water level to match the NOTRUMP code results.

Specifically, as noted in the response for RAI# 20, the NOTRUMP code is used to calculate the mass in the steam generator when the indicated narrow range level is at the safety analysis low-low steam generator water level reactor trip setpoint. In terms of heat removal capacity, the amount of mass in the steam generator at the time of reactor trip is an important parameter in determining if there is sufficient heat removal capability in the steam generators following reactor trip. As long as the mass assumed at the time of reactor trip is conservatively low, the fact that a larger volume has been used to ensure a correct initial mass in the steam generator exists is of insignificant importance to the results.

26. The licensee provides results for the Loss of Normal Feedwater Flow event reanalysis which incorporates the proposed methodology changes. To remove some of the conservatism in the steam generator water mass, the NOTRUMP steam generator water mass calculation increases the initial secondary side steam generator water level. This is demonstrated in revised UFSAR Figure 15.2-10, as the transient is initialized with approximately [ ] a,c of additional mass. Table 15.2-1 provides the sequence of events for the reanalysis, and shows that the low-low steam generator water level trip occurs approximately 10 seconds earlier than in the previous RETRAN analysis (without the higher initial steam generator mass). Please discuss why the low-low steam generator water level trip occurs earlier in the updated analysis with a higher initial steam generator mass.

Response:

It occurs earlier because in addition to [

] a,c

27. Please provide similar discussions and results of the reanalyses for the other events for which the methodology of WCAP-14882-S1-P will be applied. Include results which demonstrate that the acceptance criteria for these events, as listed NUREG-0800, "Standard Review Plan" will be satisfied.

Response:

The only other event that the models described in WCAP-14883-S1-P will be utilized for is the Feedline Break event, which results in the same type of transient as the Loss of Normal Feedwater event; that is, the initial SG mass decreases until the low-low SG water level reactor trip setpoint (modeled as a total mass value) is reached.

28. Energy discharged from a feedwater line break into containment can lead to heatup and subsequent flashing in the steam generator level instrumentation reference legs. Please discuss how this effect and the associated false high steam generator level indication is accounted for in the NOTRUMP - based steam generator water level calculation.

Response:

The effects of the energy discharge from the feedwater line break into containment and on the SG instrumentation reference legs are accounted for in the uncertainty calculations for the low-low SG water level reactor trip setpoint. An allowance is specifically included for the effects of reference leg heatup. The safety analyses typically use a low-low steam generator water level setpoint corresponding to 0% of span for this reason. The plant value would then be defined to include instrumentation uncertainties, adverse environmental effects and any reference leg heatup effects. This is the reason that the safety analyses typically have two different setpoints, one for the Loss of Normal Feedwater events where an adverse environment does not exist and one for the Feedline Break event where an adverse environment can affect the indicated low-low steam generator water level setpoint.

29. We understand that analyses using a standalone NOTRUMP model of the South Texas steam generators will be used to determine the steam generator water mass that will be present when a low level reactor trip occurs. This mass will then be used to set the reactor trip logic in the RETRAN model that will be used to analyze plant response to loss of feedwater, loss of offsite power and feedwater line breaks. The NOTRUMP computer code has many options for calculating bubble rise in the fluid nodes and drift flux in the flow links. These models will affect the water mass calculated to be in a steam generator. Please identify which models will be used to determine steam generator water mass for analysis of loss of feedwater, loss of offsite power and feedwater line breaks. Justify that these models have been verified to be accurate for the conditions that would occur within the South Texas steam generators during these events.

Response:

The [ ]^{a,c} correlation (see reference shown below) is used. This correlation was judged to be the best to use for steam generator analyses since it is based in part on data generated at the [

]^{a,c}

Reference:

[

]^{a,c}

30. For analysis of feedwater line breaks using NOTRUMP, please discuss the models used to predict break flow and liquid entrainment from the broken steam generator. Justify that the models are conservative for determining the low level trip water mass to be input into RETRAN. Provide a comparison of the break flow rate predicted by NOTRUMP to that predicted by RETRAN.

Response:

As part of the NOTRUMP-RETRAN iterations, comparisons were made between the break flows calculated by each code to ensure that the RETRAN flows are in agreement (or are conservative) with respect to the NOTRUMP flows through the point of reactor trip. The [ ]^{a,c} is used by both the NOTRUMP and RETRAN computer codes for break flow at saturated conditions. For subcooled conditions, NOTRUMP uses the [ ]^{a,c} and RETRAN uses the [ ]^{a,c}

[

]^{a,c}

Figure 30-1
Comparison of the NOTRUMP Break Flow Rate
To the RETRAN Break Flow Rate

a,c

[ ]

31. We understand that the RETRAN model of the South Texas steam generators utilizes homogeneous mixing below the steam separators and assumes perfect separation of steam above the steam separators. The feedwater lines are below the steam separators so that the fluid entering a postulated broken feedwater line would be in the homogeneous flow condition. The assumption of homogeneous flow would be conservative for calculating reactor coolant system overheating following a feedwater line break. We also understand that break flow is calculated using the [ ] a,c options, which are also conservative. Please verify that the staff's understanding is correct or discuss the conservatism of other models that are used.

Response:

The NRC is correct in that the RETRAN model utilizes homogeneous mixing volumes for the volumes below the volume associated with the primary steam separators. This results in homogeneous flow entering the postulated feedwater line break which is conservative for a heatup transient. In addition, the NRC is correct in that the [ ] a,c models were used for modeling the feedwater line break, which, as stated in the question, are conservative models for Feedline Break analyses. Additional conservatisms that are applied in the modeling of the feedwater line break event include the following:

- No main feedwater is delivered to the intact steam generators from the time the break is initiated.
- The NOTRUMP calculated mass corresponding to the low-low steam generator water level trip setpoint is [ ] a,c to provide a conservative estimate of the trip mass used in the RETRAN code.
- Minimum auxiliary feedwater flow is assumed.
- Maximum reactor coolant pump heat is assumed.
- Maximum decay heat levels are assumed.
- A very conservative criterion of demonstrating that no hot leg boiling occurs to ensure that the core remains covered with water and remains geometrically intact.