FINAL SAEFTY EVALUATION BY THE OFFICE OF NEW REACTORS
WCAP-17065-P, "WESTINGHOUSE ABWR SUBCOMPARTMENT ANALYSIS USING GOTHIC"
SOUTH TEXAS PROJECT NUCLEAR OPERATING COMPANY UNITS 3 AND 4
PROJECT NUMBER 772

1.0 INTRODUCTION

By letter dated April 29, 2010 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML101250482), South Texas Project (STP) Units 3 and 4 submitted Topical Report WCAP-17065-P, "Westinghouse ABWR Subcompartment Analysis Using GOTHIC," as part of a series of advanced boiling-water reactor (ABWR) fuel-related TRs that will support a future license amendment for STP Units 3 and 4.

Generation of Thermal-Hydraulic Information for Containments (GOTHIC) is a general-purpose thermal-hydraulics code for containment analysis developed for the Electric Power Research Institute (EPRI) by Numerical Applications, Inc. (NAI), for applications in the nuclear power industry. Specifically, the GOTHIC methodology would be used for subcompartment analysis of STP Units 3 and 4. The methodology includes the following:

- description of the nodalization
- vent flow and associated parameters
- initial conditions
- benchmark comparison of results from a GOTHIC subcompartment model and the General Electric Co. (GE) ABWR design control document (DCD) subcompartment analysis
- GOTHIC model for a representative STP Units 3 and 4 ABWR steam tunnel subcompartment analysis
- nodalization sensitivity study

This safety evaluation (SE) is based on the acceptance criteria for subcompartment analysis in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Section 6.2.1.2, "Subcompartment Analysis," Revision 3, issued March 2007, and U.S. Nuclear Regulatory Commission (NRC) staff confirmatory calculations. The NRC has previously approved the use of GOTHIC for boiling-water reactor containment analysis. This SE will specifically address the methodology with respect to its use for STP Units 3 and 4.

2.0 REGULATORY EVALUATION

STP submitted a combined operating license application for Units 3 and 4 referencing the certified ABWR design. Therefore, Title 10 of the *Code of Federal Regulations* (10 CFR) 52.79(a)(4)(i), which refers the applicant to Appendix A, Facilities, " is applicable. Production and Utilization Appendix A establishes the minimum requirements for the

“General Design Criteria for Nuclear Power Plants,” to 10 CFR Part 50, “Domestic Licensing of principal design criteria for light-water nuclear power plants. General Design Criterion (GDC) 4, “Environmental and Dynamic Effects Design Bases,” requires, in part, that structures, systems, and components important to safety shall be designed to accommodate the effects of and to be compatible with the environmental conditions associated with postulated accidents, including loss-of-coolant accidents (LOCAs).

GDC 50, “Containment Design Basis,” requires, in part, that the containment be designed so that the containment structure and its internal compartments can accommodate a LOCA. In the context of this review, this implies that the pressure differentials across the walls of the subcompartments must be less than structural limits with some margin.

In order to meet the regulations described above, SRP Section 6.2.1.2 has specific acceptance criteria. Although the SRP is not a substitute for NRC regulations and compliance is not required, an applicant is required to identify differences between design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide acceptable methods of compliance with the NRC regulations.

3.0 TECHNICAL EVALUATION

3.1 Overview

The NRC staff reviewed the applicant’s proposed use of GOTHIC for subcompartment analysis of STP Units 3 and 4. The review concentrated on those features judged most significant to the type of analysis proposed by the applicant. The NRC staff is not making a judgment about the overall acceptability of GOTHIC for licensing calculations. The NRC staff performed independent analyses to assist with the assessment.

In order for the NRC staff to better understand the scope and limitations of WCAP-17065, the staff submitted Request for Additional Information (RAI) 8, asking the applicant to clarify the scope and limitations as well as what it was seeking approval for in WCAP-17065. The applicant responded in letters dated December 28, 2010 (ADAMS Accession No. ML110030207), and March 7, 2011 (ADAMS Accession No. ML110700588).

The NRC staff reviewed the applicant’s responses to RAI 8 and found them to be acceptable because they addressed the scope and limitations for the approval of WCAP-17065. The applicant expects to use the ABWR subcompartment methodology for future subcompartment analyses with STP Units 3 and 4. The NRC staff is not approving this application for generic ABWR subcompartment analyses. WCAP-17065 contains case-specific details, such as detailed design information, mass and energy related to fuel, and friction and form losses, all of which are directly related to the design of STP Units 3 and 4. The updates also address how the applicant applies the use of GOBLIN, a computer code used to generate short-term mass and energy release input for the GOTHIC representative STP Units 3 and 4 steam tunnel model, which the staff discusses in Section 3.5 of this SE.

3.2 GOTHIC Computer Code

GOTHIC is a state-of-the-art, general-purpose, thermal-hydraulics computer program that solves the conservation equations for mass, energy, and momentum for multicomponent, multiphase flow. Interface models between phases allow for thermal nonequlibrium and unequal phase velocities. It also provides the ability to model volumes as either a “lump” or subdivided control volume (CV.) Lumped CVs represent the volume of a compartment or space as a single analytical node. Subdivided CVs allow a single volume to be represented by many nodes allowing for a more precise calculation. As a conservative measure lumped CVs are typically used as they provide higher pressures, thus introduce analysis margins into the design.

In RAI 8, the NRC staff asked the applicant to specify which version of the GOTHIC code it is using for this specific application. In a letter dated December 28, 2010 (ADAMS Accession No. ML110030207), the applicant responded that Westinghouse is currently using GOTHIC Version 7.2a for the ABWR subcompartment analysis. The NRC staff found this response to be acceptable because the staff has reviewed containment analysis applications in the past that used GOTHIC 7.2a and found them to be acceptable (ADAMS Accession No. ML0911005210).

GOTHIC is maintained by NAI for EPRI. The applicant referenced NAI 8907-09, Revision 9, which is the “GOTHIC Containment Analysis Package Qualification Report.” This report states that GOTHIC is qualified under the NAI quality assurance program, which conforms to the requirements of Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” to 10 CFR Part 50, with error reporting in accordance with 10 CFR Part 21, “Reporting of Defects and Noncompliance.”

In RAI 8, the NRC staff asked the applicant to describe the procurement methodology for GOTHIC, specifically the following:

a) Is it procured as safety related?

b) Was it developed under a program meeting 10 CFR Part 50, Appendix B and 10 CFR Part 21?

c) Describe the procurement chain for Qualification of NAI as an Appendix B supplier.

In a letter dated December 28, 2010 (ADAMS Accession No. ML110030207), the applicant responded to RAI 8, clarifying that Westinghouse is a member of the EPRI GOTHIC Advisory Group. The code is procured as a safety code, and Westinghouse uses a quality management system to maintain compliance with Appendix B to 10 CFR Part 50 and 10 CFR Part 21. Westinghouse performs periodical reviews of its software vendors as part of its quality management system program.

The NRC staff finds this response to be acceptable because the GOTHIC code is procured as a safety-related component. The staff also finds the development of the GOTHIC code under Appendix B to 10 CFR Part 50 and 10 CFR Part 21 to be acceptable because Westinghouse has procedures and processes in place to ensure that the code meets these quality assurance standards. The procurement chain for qualification of NAI as an Appendix B supplier is also acceptable, as Westinghouse qualifies and procures its software vendors.

GOTHIC has been successfully compared with a variety of data and analytic solutions. Therefore, the NRC staff’s review of the STP ABWR Units 3 and 4 subcompartment analysis concentrated on the GOTHIC models deemed to be significant for this application and on assumptions made by the applicant in applying GOTHIC to high-energy line break analyses. In addition to reviewing the information supplied by the applicant, the NRC staff performed independent calculations using the NRC-developed MELCOR containment computer program and COMPARE subcompartment computer program.

3.3 Subcompartment Modeling Methodology

The STP Units 3 and 4 ABWR GOTHIC model comprises three ABWR DCD benchmark models and one representative STP Units 3 and 4 steam tunnel model. The three benchmark models consist of the DCD volume model, [ ] volume (of the DCD volume model) without additional losses (DCD flow path coefficients used without including additional mechanical losses), and [ ] volume with additional losses (DCD flow path coefficients used, including additional mechanical losses). Each GOTHIC DCD benchmark model is compared to Transient Mass Distribution Code (TMD), which is a containment analysis code developed by Westinghouse for ice condenser containments. TMD is not approved for ABWR subcompartment analysis, but it has been used and approved for other licensee subcompartment analyses, such as large dry containments and ice condenser containments.

The GOTHIC DCD benchmark model is based on the model provided in the certified ABWR DCD and is composed of six control volumes with two boundary conditions. Figure 5-1 in the topical report displays the node diagram. The benchmark noding consists of the following:

- reactor building steam tunnel (RBST)—one lumped control volume
- control building steam tunnel (CBST)—one lumped control volume
- turbine building—one lumped control volume.
- turbine building steam tunnel (TBST) - two separate control volumes and
- atmosphere - one lumped control volume

Details on the methodology that the applicant used, such as initial conditions, vent path information, and nodalization, are provided below. Main steamline and feedwater line breaks were both simulated in the RBST. ABWR DCD Section 6.2.3.3.1 Compartment Pressurization describes the high energy line breaks and establishes the design basis for being the worst-case DBA rupture. The applicant used the mass and energy release that was included in the certified ABWR DCD for the DCD benchmark models and used GOBLIN for the representative STP Units 3 and 4 steam tunnel model.

The applicant also created a GOTHIC model that was representative of an ABWR steam tunnel in STP Units 3 and 4. This model was based on detailed design information and employed the methodology developed for the ABWR STP Units 3 and 4 subcompartment analysis that is described below. This model is not intended to provide the licensing-basis results for STP. The NRC staff conducted an audit on November 9, 2010, and documented the confirmation of the detailed design information in an audit report dated February 8, 2011 (ADAMS Accession No. ML110330133).

3.3.1 Initial Conditions

The initial conditions for the benchmark model are the same as those from the ABWR DCD. These values were chosen based on the acceptance criteria in SRP Section 6.2.1.2. Temperature was conservatively chosen as 140 degrees Fahrenheit (F), initial pressure was set to atmospheric, and the initial humidity was set to 10 percent.

3.3.2 Control Volumes

In WCAP-17065, Section 5, Case 1, the DCD benchmark case uses volume information available in Table 6.2. Cases 2 and 3 of Section 5.0 calculate volume from drawings in

Section 6.2 of the certified ABWR DCD and then conservatively reduce it by [ ]. This reduction in volume is done to account for major equipment and piping. Control volume information for the representative steam tunnel analysis in Section 6.0 is developed using detailed design information.

The NRC staff questioned the use of the [ ] reduction factor for Cases 2 and 3 of Section 5.0 during an audit on November 9, 2010, asking whether the [ ] factor creates uncertainty about the actual margin, since the amount of equipment was unknown at the time that WCAP-17065 was written. In the NRC audit report dated February 8, 2011 (ADAMS Accession No. ML110330133), the staff found that the applicant did account for equipment and piping. The calculations were not an exact comparison to the certified ABWR DCD result. These calculations were only a supplement to Case 1 in Section 5.0 of WCAP-17065. The use of the [ ] reduction factor for each room is considered to be acceptable for Cases 2 and 3 of Section 5.0 because the reduction helps determine the appropriate volumes for the case when using drawing information in the certified DCD. The volume reduction factor was used for the representative steam tunnel case in Section 6.0 of WCAP-17065.

The applicant plans to come up with a new design limit for pressure once the final detailed design is complete. Inspection, Test, Analysis, and Acceptance Criterion (ITAAC) 2.15.10 and 2.14.1 from the ABWR DCD require verification of as-built information and require a structural analysis to be performed. Section 3H.1.4.3.1.6.4 of the ABWR DCD also explains that a dynamic load safety factor of 2.0 will be applied to the final results of the steam tunnel subcompartment pressure results.

3.3.3 Droplet Modeling

The GOTHIC input for [ ] in the associated high-energy line break flow can be adjusted [ ]. The specified droplet [ ]. The staff finds the use of the [ ] to be acceptable because it [ ] and adheres to SRP Section 6.2.1.2 guidance that vent flow behavior through all flow paths and nodalized compartments should be based on a homogeneous mixture in thermal equilibrium with 100-percent entrainment.

[ ]. The staff finds this option to be acceptable because it will [ ] in the break flow and allow more energy to be transported into the break room. It also adheres to an earlier NRC staff finding that the validation of the GOTHIC drop-to-liquid conversion model, as described in the GOTHIC qualification report, is not sufficiently comprehensive to support its use for subcompartment high-energy line break licensing calculations.

However, if an analysis of a room produces subcooled break flow, such as in a reactor water cleanup (CUW) filter demineralizer room, the applicant shall evaluate the use of the nonequilibrium model in GOTHIC in parallel with the drop-to-liquid conversion [ ]. A past NRC SE identified this measure as conservative for breaks with subcooled break flow (ADAMS Accession No. ML041410566). The applicant shall apply the more conservative assumptions after performing an analysis of a break room with subcooled break flow.

3.3.4 Vent Flow Paths

Vent path information provides the details important in the calculation of mass, energy, and momentum transfer between control volumes. Vent paths for the DCD benchmark models are based on the vent path information that was available in Table 6.2-4 of the certified ABWR DCD. Table 6.2-4 provides vent area, vent length, and forward and reverse head-loss coefficients. The applicant determined the hydraulic diameter by taking the square root of the vent area provided in Table 6.2-4. Inertia length values were not available to the applicant; however, it used design information available in the ABWR DCD to develop inertia length values using the GOTHIC inertia length Equation 2-2 in WCAP-17065. The NRC staff found the use of the vent path information for the DCD benchmark cases to be acceptable because all of the information was taken from the certified ABWR DCD.

The NRC staff performed a sensitivity calculation to determine the effect that inertia length had on peak pressure, and whether the inertia length value used was conservative for peak pressure. The NRC staff established that inertia length is a key contributor to the peak pressure within the first second of the transient. The staff determined that the inertia length the applicant developed was acceptable for the DCD benchmark case, as it provided conservative results for peak pressure in comparison to the already certified ABWR DCD results in Figure 6.2-37m.

The NRC staff also discussed differences in peak pressure and the effects as a result of inertia length during the November 9, 2010, audit. As part of that discussion, the staff issued RAI 7, which asked the applicant to explain the differences observed between the ABWR DCD results and those in the GOTHIC DCD benchmark calculation. The NRC staff asked the applicant to identify possible differences that could cause variation in pressure trends and peak pressure time.

The applicant responded in a letter dated January 31, 2011 (ADAMS Accession No. ML1103402764), explaining that it did not have access to the analyses performed by GE, and that the major difference between the analysis the applicant performed and the results given in ABWR DCD Figure 6.2-37m appears to be based on the inertia length used in the analysis. The applicant performed sensitivity studies to confirm its theory and showed that this appeared to be the reason for the major difference in peak pressure.

The NRC staff witnessed sensitivity studies of the inertia length input performed by the applicant at the November 9, 2010, audit. Based on the applicant's response and the NRC staff's confirmatory calculations mentioned above, the staff finds this response to be acceptable and the values used for inertia length in the ABWR DCD benchmark calculation to be conservative.

The applicant developed flow path information for the representative ABWR steam tunnel model based on detailed design information that was provided to the applicant. The NRC staff had an opportunity to review the detailed design information during the November 9, 2010, audit to understand how the applicant arrived at the flow path information used in the representative steam tunnel model and to recognize the differences from the certified ABWR DCD flow path information.

All flow paths, with the exception of those attached to boundary conditions, account for compressibility effects within the flow paths. [

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This assumption increases the calculated pressure drop through the vent system. The NRC staff considers the use of the [ ] to be an acceptable vent critical flow correlation, which is considered to be conservative in accordance with SRP Section 6.2.1.2.

3.3.4.1 Inertia Length

During the audit on November 9, 2010, the NRC staff raised concerns about the acceptability of the use of the [ ] inertia length equation (Equation 2-2 in WCAP-17065). The concern was addressed by the fact that the applicant successfully reproduced already approved certified ABWR DCD results using the GOTHIC model. However, it was noted during the audit that the [ ] inertia length equation was developed as a best estimate equation. As a result of discussions with the applicant, the NRC staff issued RAI 9 asking the applicant to justify the use of the inertia length Equation 2-2 in WCAP-17065 as a conservative assumption, to clarify its use with respect to validation and verification (V&V) in GOTHIC, and to provide the relevance of the V&V report with respect to the inertia equation and WCAP-17065.

The applicant responded in a letter dated February 21, 2011 (ADAMS Accession No. ML110550634), explaining that the equation provides a best estimate for a flow path connecting two lumped volumes. The formula's development came from comparisons of lumped models with computational fluid dynamic models for transient response of single-phase flow through a junction between two control volumes due to initial differential pressure across the junction.

As part of the response to RAI 9, the applicant prepared several models for tests in which room-to-room pressure differentials were measured. The applicant provided a direct comparison of differential pressure results between a GOTHIC model using room center-to-center distance and a GOTHIC model using Equation 2-2 to demonstrate the use of Equation 2-2 as a comparably conservative approach to the center-to-center method and to show that calculated peak pressures still bound the provided test data.

The applicant revised cases from the GOTHIC qualification report for tests D-1, D-15, and D-16 from the Battelle Frankfurt Model Containment and test V21.1 from the Heissdampfreaktor facilities. The results presented for the time-dependent differential pressures in each case compared very well between the Equation 2-2 model and the cell center-to-center model. For most cases, the model using Equation 2-2 was conservative compared to the test data and agreeable to the center-to-center model predictions. For those cases in which data were not bounded, the Equation 2-2 model and the center-to-center model compared very well. The staff found that the comparison to tests D-1 and D-15 best represents the ability of the GOTHIC model using Equation 2-2 to be used for the analyses in WCAP-17065. The results for these two tests offer evidence that Equation 2-2 can provide conservative results in comparison to the test data and agreeable results to inertia lengths calculated using a center-to-center approach. Based on this information, the NRC staff determined that this response is acceptable and that the use of Equation 2-2 in WCAP-17065 is acceptable for subcompartment analyses of STP ABWR Units 3 and 4.

3.3.4.2 Friction and Form Losses

Loss coefficients for flow paths include friction and form losses. In the representative steam tunnel model, the applicant used AEC-TR-6630, "Handbook of Hydraulic Resistance; Coefficients of Local Resistance and of Friction" (Idel'chik 1966). This allowed the applicant to develop loss coefficients for all associated orifices, turns, contractions, and expansions in the flow path. The applicant calculated the friction portion of the loss coefficient using Equation 2-3 from WCAP-17065. The information used was based on the geometric information available from the detailed design information. The applicant will update this information in its GOTHIC model as the detailed design information is finalized for STP Units 3 and 4.

In evaluating the DCD benchmark model friction and form losses, the staff reviewed how the applicant arrived at the values used during the November 9, 2010, audit. For the DCD benchmark model, the NRC staff found that the loss coefficients used came directly from the certified ABWR DCD in Table 6.2-4, and that they included the 1.7 mechanical loss coefficient provided in Table 6.2-4a.

The NRC staff determines that the loss coefficients using both Idel'chik and values from the certified ABWR DCD are acceptable. The use of Idel'chik was an accepted practice in previous licensee containment analyses that were approved by the NRC staff. The applicant will revise the loss coefficient values for the representative STP Units 3 and 4 GOTHIC model once final detailed design information is available to ensure that the most accurate values are used in the GOTHIC subcompartment analysis. The NRC staff also determines that the values used for the DCD benchmark case are acceptable because they are taken directly from the certified ABWR DCD.

3.4 GOTHIC Design Control Document Benchmark Model and Results

Section 5 of WCAP-17065 presents the GOTHIC benchmark model and results. Figure 5-1 of WCAP-17065 provides the GOTHIC node diagram for the DCD benchmark analyses. This node diagram is based on Figure 6.2-37b of the certified ABWR DCD. The applicant also provided its results from the DCD benchmark models (DCD volume model, [ ] volume model without additional losses, and [ ] volume model with additional losses) and compared them to certified ABWR DCD results and TMD results.

The NRC staff focused its review on the main steamline break (MSLB) results provided in WCAP-17065, Figure 5-2, which compares the results of the DCD volume benchmark model, the TMD, and the certified ABWR DCD. The MSLB is the limiting case for the ABWR DCD subcompartment analysis. Figure 5-2 of WCAP-17065 shows peak pressure results up to 0.5 seconds. The staff noted that the GOTHIC DCD benchmark model provided conservative results with respect to the certified ABWR DCD results in the first 0.5 seconds. The staff asked to review the results in their entirety during the audit on November 9, 2010.

The NRC staff reviewed the major differences among the results provided during the audit. The staff noted that there were major differences in the peak pressure within the first 0.5 seconds, and also in the steep pressure drop that occurs around 1 second. The applicant evaluated mass and energy data from the certified ABWR DCD, which resulted in a finding that the drop in pressure around 1 second was the result of the mass and energy input. The mass and energy input for the DCD benchmark models comes from Table 6.2-4b of the certified ABWR DCD. The applicant stated that the mass and energy input appears to be the result of a hand calculation. The NRC staff did not have enough information available from the ABWR DCD or the ABWR final safety evaluation report to determine if this was true. As ABWR DCD mass and energy results will not be used in the GOTHIC methodology for future analyses of STP Units 3 and 4, the staff determined that this drop in pressure did not need to be addressed.

To resolve the differences in the results for the first 0.5 seconds, the NRC staff submitted RAI 7. The staff's confirmatory calculations found that the peak pressure is sensitive to inertia length. By reducing the inertia length, the NRC staff found that the peak pressure could be lowered to better match the results of the DCD. The response to RAI 7 addresses the staff's concern about differences between the GOTHIC DCD benchmark model and the approved results in the certified ABWR DCD, and the NRC staff finds the response to RAI 7 to be acceptable, as mentioned earlier in the report.

The NRC staff performed confirmatory analyses of the DCD MSLB benchmark model. The staff used the same input that the applicant provided in Appendix A. In gathering information for the confirmatory calculation, the NRC staff submitted RAI 6 asking the applicant to clarify information provided in WCAP-17065 Tables A-1, A-2, and A-3 and to elaborate on how the values provided in the table were chosen.

The applicant responded to RAI 6 in a letter dated January 31, 2011(ADAMS Accession No. ML110340276). The response described in more detail how the applicant arrived at the values used in Tables A-1, A-2, and A-3 and provided a description of the differences among the tables and the reason loss coefficients and other values are different from case to case.

The NRC staff found the applicant's response to RAI 6 to be acceptable because it clarifies the information provided in Table A-1, Table A-2, and Table A-3 and how that information relates to each GOTHIC model created in WCAP-17065. A clearer understanding of this information was critical because the NRC staff needed it to perform the confirmatory analyses accurately. The results of the NRC staff's confirmatory analyses showed that the applicant's DCD benchmark calculations were acceptable and conservative with respect to the certified ABWR DCD results.

3.5 STP Units 3 and 4 Representative Steam Tunnel GOTHIC Model and Results

Section 6 of WCAP-17065 presents the GOTHIC representative steam tunnel model for STP Units 3 and 4. Figure 6-1 of WCAP-17065 presents the nodalization diagram for the model. This diagram is based on detailed design drawings of STP Units 3 and 4. The Figure 6-1 nodalization diagram is more refined than the diagram presented in Figure 5-1 of WCAP-17065. [

]. Figures 6-2 through 6-5 provide the results for an MSLB and a feedwater line break for the representative steam tunnel model.

The staff focused its review on the MSLB portion of the model and results, as this provided the limiting case with respect to peak pressure. Mass and energy for this particular analysis was generated by GOBLIN. GOBLIN is currently under staff review as part of the fuel-related topical reports submitted by STP. A separate SE will apply to the use of GOBLIN for ABWR containment analyses.

The staff conducted an audit on November 9, 2010, which allowed the staff to evaluate the representative steam tunnel GOTHIC model. The NRC staff confirmed the dimensions describing the new interface volumes in the model. The applicant also confirmed that it planned to use the GOTHIC methodology to reperform the subcompartment analysis once the final detailed design is complete for STP Units 3 and 4. The applicant also explained that the results in WCAP-17065 are not intended to be the licensing basis for STP Units 3 and 4.

The NRC staff performed independent confirmatory analyses using the information provided in Appendix A to WCAP-17065. The NRC staff confirmed that the results of the representative steam tunnel GOTHIC model are conservative. The model employs the subcompartment methodology assumptions described in Section 3.3 of this SE. In RAI 5, the NRC staff also asked the applicant to provide the GOTHIC input deck for further review of the nodalization sensitivity study and pressure transients. In RAI 1, the NRC staff asked the applicant to submit its mass and energy release data used for the analysis to support the staff's confirmatory and sensitivity calculations. The applicant submitted both the GOTHIC input deck and the GOBLIN mass and energy data used for the MSLB in the representative steam tunnel model. The NRC staff was able to confirm that the methodology described above did provide results that were acceptable compared to the NRC staff's confirmatory calculations.

3.5.1 Nodalization Sensitivity Study

The applicant performed a nodalization sensitivity study for an MSLB in the representative steam tunnel GOTHIC model. The CBST was chosen to be broken into more nodes because its long corridor could have an impact on peak pressure because of inertial effects. The CBST was first broken into two separate control volumes. When the case was executed with an MSLB, the pressure measured in the RBST resulted in a less than 1-percent increase in pressure relative to the base case.

The applicant also divided the CBST into five control volumes and ran another MSLB case. The peak pressure in the RBST from this case resulted in about a 1.1-percent increase relative to the base case and a 0.25-percent increase relative to the previous two-node case.

In order to better understand the applicant's nodalization sensitivity study and ensure that a proper node diagram had been chosen, the staff submitted RAI 4 asking the applicant to provide results for a RBST nodalization sensitivity study and to elaborate on the CBST nodalization sensitivity study to ensure that the results provided are acceptable for this analysis.

The applicant responded to RAI 4 in a letter dated January 31, 2011 (ADAMS Accession No. ML110340276), providing a two-part approach. First, the applicant expanded on the CBST sensitivity study by performing two more cases, one dividing the CBST into a total of 8 nodes and a second dividing it into 10 nodes. Each case indicated a less than 2-percent change from the 1-node base case. Second, the applicant performed a sensitivity study on the RBST. The applicant divided the RBST node into cases using 3, 5, and 10 total nodes. The study found that a pressure wave exists that results in pressure oscillations throughout the various nodes used. The oscillations produce localized pressure changes based on the location of the wave and size of the node. The applicant believed that this did not represent the average pressure observed along the entire length of the walls in the RBST, which is the pressure sought in the analysis. The pressure the applicant reported is based on the midpoint of the pressure waves observed in GOTHIC. The applicant showed that the peak pressure converges for the 5- and 10-node cases. The overall value is less than that observed for the CBST case.

The applicant performed additional studies to show that, when the break volume is modeled using a distributed parameter modeling approach, the pressure of the break cell approaches the stagnation pressure of the broken pipe. This modeling was performed using the GOTHIC subdivide feature. Two sensitivity studies that were performed to show the impact of this revealed pressures in the break node on the order of several hundred pounds per square inch for both cases.

The NRC staff also discussed this information during the November 9, 2010, audit and conducted its own independent sensitivity studies to confirm the acceptability of the final node diagram used for the GOTHIC subcompartment analysis. The NRC staff confirmed the applicant's results and found them to be acceptable. The NRC staff finds the applicant's response to RAI 4 to be acceptable based on this information, which shows the convergence values, and on confirmation of the applicant's results through NRC staff's sensitivity studies.

4.0 CONCLUSIONS

The NRC staff reviewed the applicant's proposed use of GOTHIC for the ABWR subcompartment analysis of STP Units 3 and 4. The review concentrated on those features judged most significant to the type of analysis proposed by the applicant. The NRC staff is not making a judgment about the overall acceptability of GOTHIC for licensing calculations.
The NRC staff performed independent analyses to assist with the assessment.

The NRC staff finds that the use of the subcompartment methodology, which includes the initial conditions, control volume information, droplet modeling, and vent path assumptions such as inertia length and friction and form losses, is acceptable as approved in this SE for use in the STP Units 3 and 4 ABWR subcompartment analysis.

The NRC staff conducted an audit on November 9, 2010, to support the review of this subcompartment methodology and performed sensitivity and confirmatory calculations to ensure that the results in WCAP-17065 were acceptable and conservative. Based on the staff's technical evaluation, the NRC staff finds WCAP-17065-P to be acceptable.

The staff review of the models and benchmarks noted concerns resulting in one limitation and two conditions on the use of ABWR subcompartment methodology, which have been committed to in WCAP-17065:

- Limitation 1: The approval of WCAP-17065 is only for STP Units 3 and 4. The NRC staff is not approving this application for generic ABWR subcompartment analyses. WCAP-17065 contains case-specific details, such as detailed design information, mass and energy release, and friction and form losses, that are directly related to the STP Units 3 and 4 design.

- Condition 1: The applicant used GOBLIN to generate mass and energy release data for the representative STP 3 and 4 steam tunnel model. This SE is not addressing the acceptability of the use of GOBLIN for mass and energy generation for the ABWR or the STP Units 3 and 4 application. A separate topical report was submitted for the use of GOBLIN with ABWR applications; the NRC staff will address its acceptability in a separate SE. The mass and energy generated in this analysis was used to demonstrate a representative release for an MSLB. Future licensing-basis subcompartment analyses will require the use of an approved mass and energy release code.

- Condition 2: For subcooled discharge conditions, the applicant shall calculate the maximum pressure by use of the non-equilibrium model in GOTHIC in parallel with considering the range of drop to liquid conversion modeling. Past NRC SEs have identified this measure as conservative for breaks with subcooled break flow (ADAMS Accession Nos. ML041410566 and ML0407606380).

5.0 REFERENCES

1. WCAP-17065-P, “Westinghouse ABWR Subcompartment Analysis Using GOTHIC,” Westinghouse Electric Company, April 2010 (ADAMS Accession No. ML101250482).

2. Standard Review Plan, Section 6.2.1.2, “Subcompartment Analysis,” U.S. NRC, March 2007.

3. South Texas Project Letter (U7-C-STP-NRC-100261) from Head, S., to USNRC. “Response to Request for Additional Information,” dated December 28, 2010 (ADAMS Accession No. ML110030207).

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11. GOTHIC Containment Analysis Package User Manual Version 7.2b, NAI 8907-02, March 2009.

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