Attachment 2

WCAP-17065-NP-A

Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC

Non-Proprietary Version

U7-C-NINA-NRC-120054

Westinghouse Non-Proprietary Class 3

WCAP-17065-NP-A
Revision 0

July 2012

Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC

Westinghouse

WCAP-17065-NP-A
Revision 0

Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC

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July 2012

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*Electronically approved records are authenticated in the electronic document management system.

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

April 9. 2012

Mr. Scott Head, Manager
Regulatory Affairs
Nuclear Innovation North America, LLC
4000 Avenue F
Bay City, TX 77414

SUBJECT: FINAL SAFETY EVALUATION FOR SOUTH TEXAS PROJECT WCAP-17065-P, "WESTINGHOUSE ABWR SUBCOMPARTMENT ANALYSIS USING GOTHIC"

Dear Mr. Head:

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 to the U.S. Nuclear Regulatory Commision (NRC) staff Topical Report (TR) 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. By letter dated August 9, 2011 (ML112160055), an NRC advanced safety evaluation (SE) regarding approval of TR WCAP-17065-P was provided for your review and comments. By an email dated August 31, 2011 (ML120520070), STP commented on the SE. The NRC's disposition of STP comments on the SE are discussed in Enclosures 3 and 4 to this letter.

The NRC staff has found that TR WCAP-17065-P is acceptable for referencing in licensing applications for STP Units 3 and 4 designed ABWR reactors to the extent specified and under the limitations and conditions delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that Westinghouse publish accepted proprietary and non-proprietary versions of this TR within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The accepted versions shall include an "-A" (designating accepted) following the TR identification symbol.

Document transmitted herewith contains sensitive unclassified information. When separated from the enclosure, this document is "DECONTROLLED."

As an alternative to including the requests for additional information (RAIs) and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.

2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, Westinghouse and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

David B. Matthews, Director
Division of New Reactor Licensing
Office of New Reactors

Project No. 0772

Enclosures:
1. Final SE (non-proprietary version)
2. Final SE (proprietary version)
3. Resolution of comments (non-proprietary version)
4. Resolution of comments (proprietary version)

cc w/o encl: See next page

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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. [

].
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).

4. South Texas Project Letter (U7-C-NINA-NRC-110003) from Head, S., to USNRC. "Response to Request for Additional Information," dated January 31, 2011 (ADAMS Accession No. ML1103402764).

5. South Texas Project Letter (U7-C-NINA-NRC-110021) from Head, S., to USNRC. "Response to Request for Additional Information," dated February 21, 2011 (ADAMS Accession No. ML110550634).

6. South Texas Project Letter (U7-C-NINA-NRC-110040) from Head, S., to USNRC. "Response to Request for Additional Information," dated March 7, 2011 (ADAMS Accession No. ML110700588).

7. Final Safety Evaluation by the Office of Nuclear Reactor Regulation for Westinghouse Electric Company Topical Report WCAP-16608-P, "Westinghouse Containment Analysis Methodology," (TAC Number MD2953), dated March 31, 2009 (ADAMS Accession No. ML0911005210).

8. Final Safety Evaluation by the Office of Nuclear Reactor Regulation for Amendment Number 139 to Facility Operating License Number NPF-47, Entergy Operations, Inc., River Bend Station, Unit 1 (TAC Number MB5096), dated May 20, 2004 (ADAMS Accession No. ML041410566).

9. Regulatory Audit Summary of the South Texas Project Nuclear Operating Company Topical Report, WCAP-17065-P, "Westinghouse Subcompartment Analysis Using GOTHIC," dated February 8, 2011 (ADAMS Accession No. ML110330133).

10. GOTHIC Containment Analysis Package Technical Manual Version 7.2b, NAI 8907-0, March 2009.

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

12. GOTHIC Containment Analysis Package Qualification Report Version 7.2b, NAI 8907-09, March 2009.

<u>RESOLUTION OF SOUTH TEXAS PROJECT NUCLEAR OPERATING COMPANY COMMENTS ON DRAFT SAFETY EVALUATION FOR TOPICAL REPORT WCAP-17065-P "WESTINGHOUSE ABWR SUBCOMPARTMENT ANALYSIS USING GOTHIC" SOUTH TEXAS PROJECT NUCLEAR OPERATING COMPANY UNITS 3 AND 4 PROJECT NUMBER 772</u>

By email dated August 13, 2011 (ADAMS No. ML120520070), South Texas Project Nuclear Operating Company STP provided 14 comments on draft Safety Evaluation (SE) for Topical Report (TR) WCAP-17065-P, "Westinghouse ABWR Subcompartment Analysis Using Gothic". Some information in the draft SER for this TR was identified by the applicant as proprietary and will be marked with brackets "[ ]" accordingly and the bracketed material will be removed from the public version of this SE.

<u>Draft SE comments for TR WCAP-17065-P:</u>

1. The second sentence of Section 1.0, Paragraph 3, reads:

   The NRC has previously approved the use of GOTHIC for boiling-water reactor containment analysis on a case-by-case basis.

   STP commented that WCAP-16608 was reviewed/approved by NRC for a generic BWR Mark I containment model, therefore approval "on a case-by-case basis" should be removed. The NRC staff agreed with the applicant's assessment, and the sentence was revised as follows:

   The NRC has previously approved the use of GOTHIC for boiling-water reactor containment analysis.

2. The last sentence of Section 3.2, Paragraph 1, reads:

   As a conservative measure lumped CVs are typically used as they provide higher pressures, thus introduce safety margins into the design.

   STP commented that a safety margin is the difference between the design limit and failure limit recommended "analysis margins". The NRC staff agreed with the applicant's assessment, and the sentence was revised as follows:

   As a conservative measure lumped CVs are typically used as they provide higher pressures, thus introduce analysis margins into the design.

3. The last sentence of Section 3.2, Paragraph 2 reads:

   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) on a case by case basis.

Per item #1 above, STP had the same comment. The NRC staff agreed and the sentence was revised as follows:
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).

4. Sentences 2 and 3 of Section 3.3, Paragraph 1 reads:

   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).

STP identified the above bracketed information as proprietary. The NRC staff agreed and these items were removed from the public version of the SER.

5. The beginning of the second paragraph of Section 3.2 reads:

   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 note diagram. The benchmark nodding consists of the following:

   - *reactor building steam tunnel (RBST)—two separate lumped control volumes*
   - *control building steam tunnel (CBST)—one lumped control volume*
   - *turbine building—four separate lumped control volumes.*

   STP clarified that this description was for their proprietary representative model and not the model shown in Figure 5-1. NRC Staff agreed and this was rewritten as follows:

   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*

6. The third sentence of Section 3.3.1 reads:

Temperature was conservatively chosen as 140 degrees Fahrenheit (F), initial pressure was set to atmospheric, and the initial humidity was set to zero percent.

STP clarified that 10 percent was the benchmark in the DCD. NRC Staff agreed.

Temperature was conservatively chosen as 140 degrees Fahrenheit (F), initial pressure was set to atmospheric, and the initial humidity was set to 10 percent.

7. The second sentence of Section 3.3.2, Paragraph one reads:

Cases 2 and 3 of Section 5.0 calculate volume from drawings in the certified ABWR DCD and then conservatively reduce it by.....

STP cited that Section 6.2 of the DCD was a clearer reference. NRC Staff agreed

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.....

8. STP identified the following bracketed information as proprietary in Section 3.3.2. The NRC staff agreed and these items were removed from the public version of the SER.

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 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.

9. The last sentence of Section 3.3.2, Paragraph 2 reads as follows:

Reduction factor was used for the representative steam tunnel case in Section 6.0 of WCAP-17065.

STP suggested the following clarification to this sentence and the NRC Staff agreed:

The volume reduction factor was used for the representative steam tunnel case in Section 6.0 of WCAP-17065.

10. STP identified the following bracketed information as proprietary in Section 3.3.3. The NRC staff agreed and these items were removed from the public version of the SER.

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.

11. STP identified the following bracketed information as proprietary in the last paragraph of Section 3.3.4. The NRC staff agreed and these items were removed from the public version of the SER.

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

12. STP identified the following bracketed information as proprietary in the first paragraph of Section 3.3.4.1. The NRC staff agreed and these items were removed from the public version of the SER.

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.

13. STP identified the following bracketed information as proprietary in the first paragraph of Section 3.4. The NRC staff agreed and these items were removed from the public version of the SER.

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.

14. STP identified the following bracketed information as proprietary in the first paragraph of Section 3.5. The NRC staff agreed and these items were removed from the public version of the SER.

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.

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1 INTRODUCTION AND BACKGROUND

Section 6.2.1.2 of NUREG-0800 requires design analyses be performed to demonstrate that the walls can withstand the short-term differential pressure pulse following a large, high energy line break (HELB) within each primary containment subcompartment. Westinghouse currently uses the Transient Mass Distribution code, TMD, code (Reference 2) to perform the subcompartment design analyses.

NRG Energy/South Texas Project Nuclear Operating Company (STPNOC) submitted a combined construction and operating license application (COLA) for two advanced boiling water reactor (ABWR) units at their South Texas site. Westinghouse is working with Toshiba and STPNOC to help license STP Units 3 and 4.

The code that was used by General Electric (GE) to perform the ABWR subcompartment design analyses for the design control document (DCD) (Reference 3) is not available to Westinghouse or Toshiba. Therefore, an alternative code/methodology is required to address potential future ABWR design changes.

An ABWR subcompartment design analysis methodology that uses the GOTHIC code is described in this report. Westinghouse is planning to use GOTHIC for future containment analysis work. Using a single code for containment analyses will simplify code maintenance and user qualification activities. Furthermore, TMD has modeling limitations that do not exist in GOTHIC.

The GOTHIC code qualification report (Reference 4) compares model results to a number of tests that represent conditions similar to those that would be observed in a typical subcompartment analysis. This provides a significant level of confidence that GOTHIC is a suitable tool for performing subcompartment analyses. To provide an additional level of confidence, Westinghouse performed a benchmark comparison to the approved TMD subcompartment analysis methodology using GOTHIC and TMD models of the ABWR steam tunnel subcompartment configuration that is described in the ABWR DCD.

The purpose of this report is to obtain NRC approval for the Westinghouse implementation of the GOTHIC subcompartment analysis methodology for the ABWR as described in Section 2 of this report. This methodology will be used to analyze breaks located in subcompartments outside of the primary containment (i.e., secondary containment and the steam tunnel system). This document provides:

1. A description of the GOTHIC subcompartment modeling methodology.

2. Benchmark comparison results from a GOTHIC subcompartment model and a TMD subcompartment model.

3. A comparison of the GOTHIC subcompartment modeling methodology to the Standard Review Plan Requirements (Reference 5).

4. Sample transient results for a representative ABWR steam tunnel subcompartment analysis.

2 SUBCOMPARTMENT MODELING METHODOLOGY

This section describes the ABWR subcompartment modeling methodology for which approval is being sought. This section describes the input development method to be used for Westinghouse ABWR subcompartment analyses.

2.1 CONTROL VOLUMES

Control volumes (CV) are used in GOTHIC to represent the various rooms in the system being analyzed. Input data for control volumes is based on the room geometry. Once the room volumes are determined, they are conservatively reduced. This is done by subtracting the volume of major equipment and major piping, and then reducing the calculated volumes by an additional percentage. This additional reduction factor is typically [ ]^{a,c}, with some exception for rooms that have a large amount of small equipment, small piping, cable trays, etc. The typical GOTHIC control volume input values are calculated as shown in Equation 2-1.

[ ]^{a,c} 2-1

2.2 DROPS

The GOTHIC input for the drops can be adjusted to make the vapor region look like a homogeneous mixture of steam, water (as small drops), and gas. [

]^{a,c} The GOTHIC code models the corresponding heat and mass transfer between the drops and atmosphere. Because the specified diameter of the incoming drops is very small, the drops quickly come into thermal and velocity equilibrium with the vapor phase.

2.3 VENT PATHS

Flow paths are used in GOTHIC to transfer mass, energy, and momentum between control volumes. Input data for flow paths is based on the flow path geometry.

Flow path area is based on the flow path geometric data, and similar to the control volume input, the total area is further reduced. This is done by reducing the calculated total flow area by subtracting major piping and insulation along with an additional [ ]^{a,c} reduction in available flow area.

Inertia lengths are calculated in accordance with GOTHIC guidance for calculating inertia lengths. The equation for inertia length is as follows:

[ ]^{a,c} 2-2

In Equation 2-2, L_I is the junction inertia length, A_j is the junction area, D_h is the junction hydraulic diameter, L_o is the orifice wall thickness, L_1 and L_2 are the distances from the attached cell centers to the area change (orifice, expansion, contraction, etc.) and A_1 and A_2 are the expanded areas on either side of the junction opening.

Loss coefficients for flow paths include form losses and friction losses. Reference 1 is the basis for all form losses used for flow paths. Using Reference 1, contributions to the overall loss coefficient from orifices, turns, contractions, and expansions are calculated. Because loss coefficients are a function of the relevant flow area in which they are associated, losses are then biased to the flow path flow area.

The friction loss portion of the loss coefficient is calculated using Equation 2-3.

$$K = \frac{f * L_{eq}}{D_h} \qquad \text{2-3}$$

In Equation 2-3, f is the friction factor, L_{eq} is the equivalent length, and D_h is the hydraulic diameter. A constant value of [ ]^{a,c} is used for the friction factor, f, in Equations 2-3 and 2-4.

The equivalent length (L_{eq}) is calculated in the same manner as TMD (Reference 2). Equation 2-4 shows the method for calculating the equivalent length.

$$\left[\qquad \qquad \right]^{a,c} \qquad \text{2-4}$$

(Note: the subscript 3 denotes the minimum flow area flow path)

In Equation 2-4, $f_{1\text{-}3}$ is the friction factor, L_1 is the length of the upstream room, L_2 is the length of the downstream room, L_3 is the length of the flow path between the rooms (i.e., door or wall length), D_1 is the hydraulic diameter of the upstream room, D_2 is the hydraulic diameter of the downstream room, D_3 is the hydraulic diameter of the flow path between the rooms, A_1 is the reduced flow area of the upstream room, A_2 is the reduced flow area of the downstream room, and A_3 is the reduced flow area of the flow path between the rooms.

All flow paths, with the exception of those attached to boundary conditions, account for compressibility effects within the flow paths. In addition, the homogeneous equilibrium choking model (HEM) is used in these flow paths. It considers a mixture of steam, water, and gas at equal temperature and velocity to calculate the choked flow rate through the flow paths.

A no slip condition between the liquid and vapor phases is assumed through the system. This assumption increases the calculated pressure drop through the vent system. [

]^{a,c}

2.4 INITIAL CONDITIONS

Consistent with the accepted methods for calculating the subcompartment peak pressure, [

]^{a,c}.

3 COMPARISON OF GOTHIC METHODOLOGY TO STANDARD REVIEW PLAN REQUIREMENTS

Table 3-1 Comparison of Gothic Methodology to Standard Review Plan Requirements

a,c

Table 3-1 (cont.) Comparison of Gothic Methodology to Standard Review Plan Requirements

a,c

4 GOTHIC VALIDATION TESTING

As part of the GOTHIC Qualification Report (Reference 4), GOTHIC model results were compared with and benchmarked against the results from a variety of test facilities. Included in these tests are the Battelle-Frankfurt Test Facility (BFMC) and Heissdampfreaktor (HDR). Each of these test facilities contain a variety of different subcompartment configurations. Further information on these test facilities, along with comparisons to GOTHIC, may be found in Reference 4.

5 GOTHIC BENCHMARK MODEL DESCRIPTION AND RESULTS

Benchmark models were developed to compare GOTHIC results to those from the NRC approved subcompartment code (TMD). For this benchmark, a steam tunnel model, representative of the one described in the ABWR DCD analysis, was used as the basis for the TMD and GOTHIC benchmarking. Some calculated inputs that are required for TMD and GOTHIC were not provided in the ABWR DCD. For the TMD model, these calculated inputs were determined using TMD guidance. GOTHIC models are similar to the TMD models, with an exception in the areas that GOTHIC guidance deviates from TMD guidance.

Three sets of benchmark models were created and analyzed for both feedwater line breaks (FWLB) and main steam line breaks (MSLB). These three sets of models are intended to show the impact of parameter changes to provide an additional level of confidence in the code to code comparison. The three models are described as follows:

1. DCD Volume Model – These models are based on the volume data provided in the DCD. DCD flow path loss coefficients are used for flow paths including the additional mechanical losses given in the DCD.

2. [ ][a,c] Calculated Volume Model without Additional Losses – These models use volume input data that is calculated from available drawings. DCD flow path loss coefficients are used for flow paths without including the additional mechanical losses given in the DCD.

3. [ ][a,c] Calculated Volume Model with Additional Losses – These models use volume input data that is calculated from available drawings. DCD flow path loss coefficients are used for flow paths including the additional mechanical losses given in the DCD.

The GOTHIC noding diagram for the benchmark analyses may be viewed in Figure 5-1. The key input data for the GOTHIC subcompartment benchmark models are presented in Tables A-1 and A-2 of Appendix A.

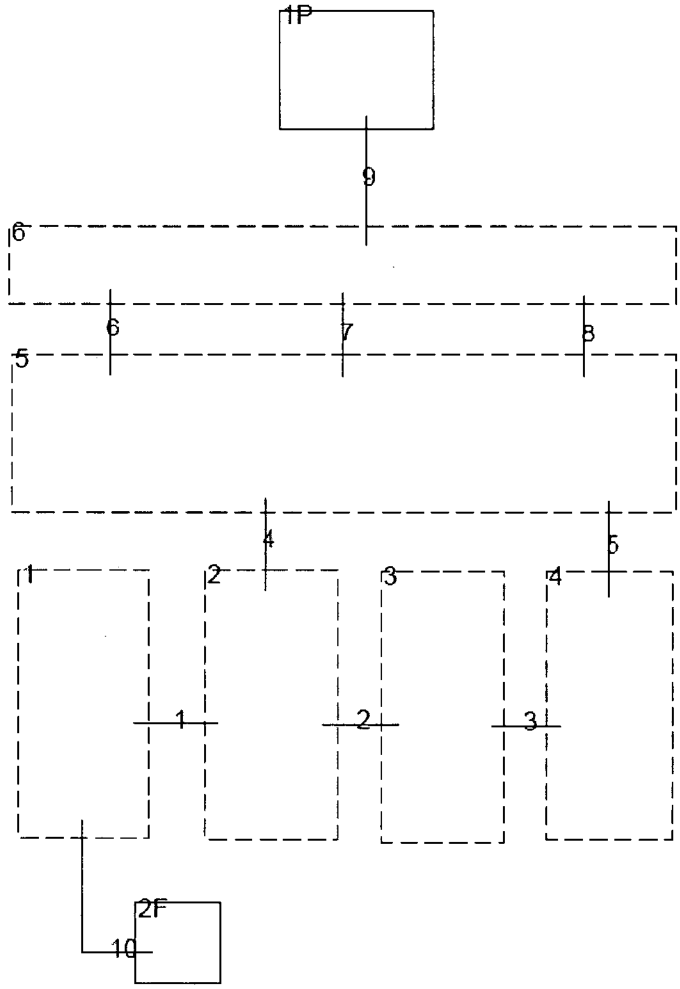

Figure 5-1 GOTHIC Benchmark Noding Diagram

5.1 MAIN STEAM LINE BREAK COMPARISON

The results of the MSL HELB in the reactor building steam tunnel are presented in Figures 5-2 through 5-4. Table 5-1 shows the "%" difference between the TMD and GOTHIC peak calculated pressures.

Note that the DCD results are shown only as a reference point to the original DCD analysis. The GOTHIC benchmark model is not intended to match the DCD results. Instead, the GOTHIC benchmark model is intended to be compared to the TMD results.

Table 5-1 Main Steam Line Break Benchmark Results			
Case	TMD Result (psia)	GOTHIC Result (psia)	Difference (%)
MSL DCD Volume	24.4	24.5	0.41
MSL [ ]^{a,c} w/o Add'l Losses	23.6	23.6	0.00
MSL [ ]^{a,c} w/ Add'l Losses	23.7	23.8	0.42

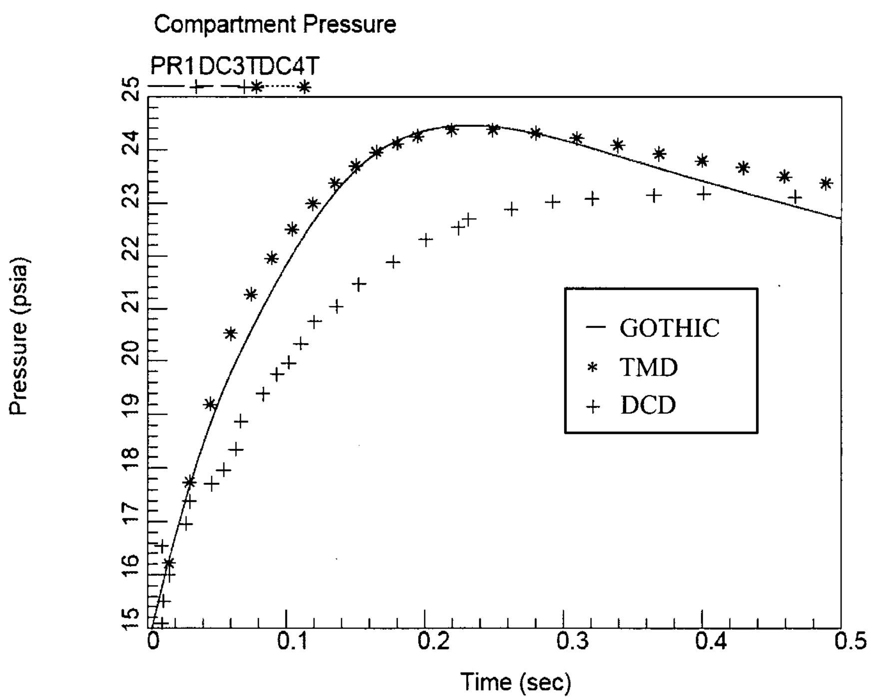

Figure 5-2 GOTHIC/TMD MSLB Pressure Comparison for DCD Volume Case

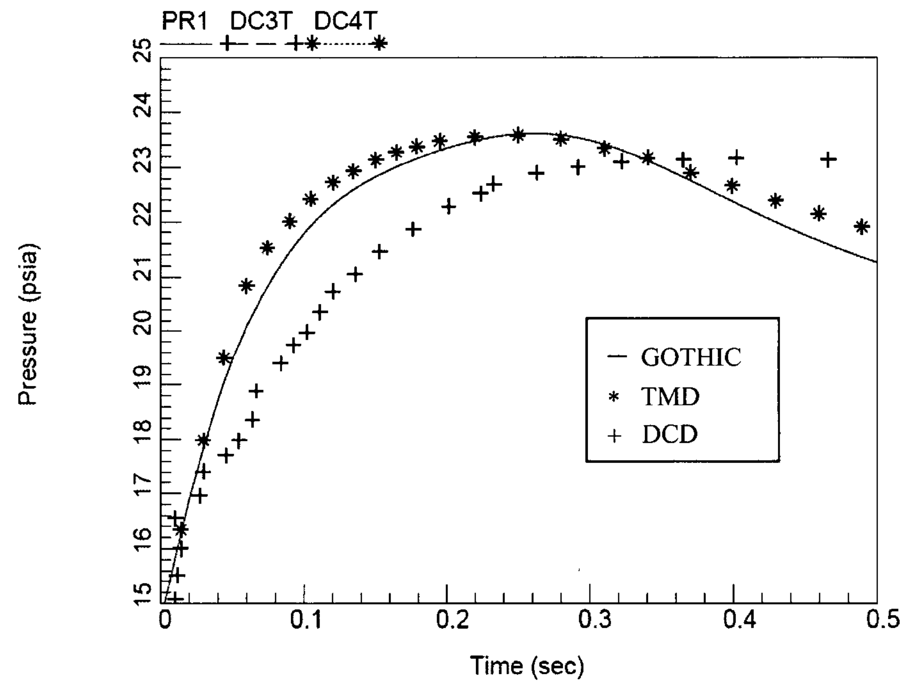

Figure 5-3 GOTHIC/TMD MSLB Pressure Comparison for [ ]^{a,c} Calculated Volume Case without Additional Losses

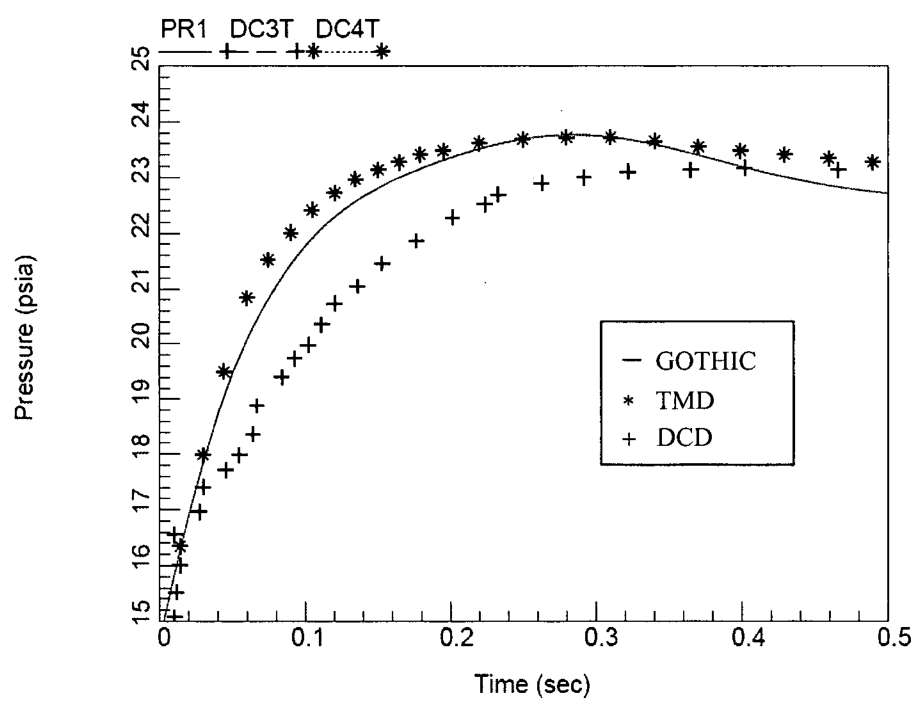

Figure 5-4 GOTHIC/TMD MSLB Pressure Comparison for [ ]^{a,c} Calculated Volume Case with Additional Losses

5.2 FEEDWATER LINE BREAK COMPARISON

The results of the FWL HELB in the reactor building steam tunnel are presented in Figures 5-5 through 5-7. Throughout these plots, the solid line represents the GOTHIC results and the dashed line represents the TMD results. Table 5-2 shows the "%" difference between the TMD and GOTHIC peak pressures. Unlike the steam line break, the DCD does not provide the transient results for the FWLB.

Table 5-2 Feedwater Line Break Benchmark Results

Case	TMD Result (psia)	GOTHIC Result (psia)	Difference (%)
FWL DCD Volume	16.2	16.6	2.47
FWL [ ]^{a,c} w/o Add'l Losses	16.0	16.2	1.25
FWL [ ]^{a,c} w/ Add'l Losses	16.0	16.2	1.25

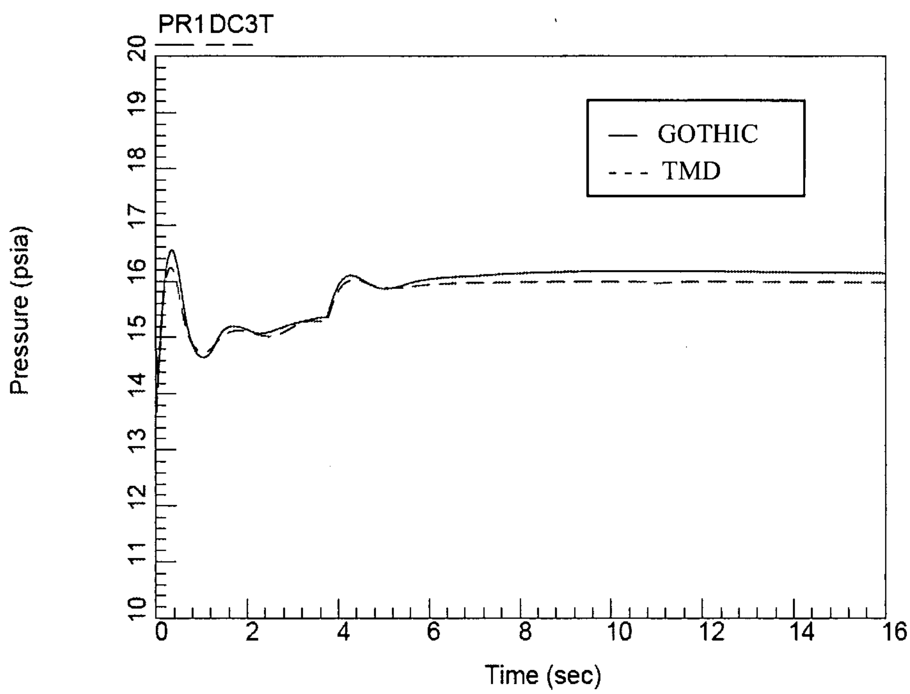

Figure 5-5 GOTHIC/TMD FWLB Pressure Comparison for DCD Volume Case

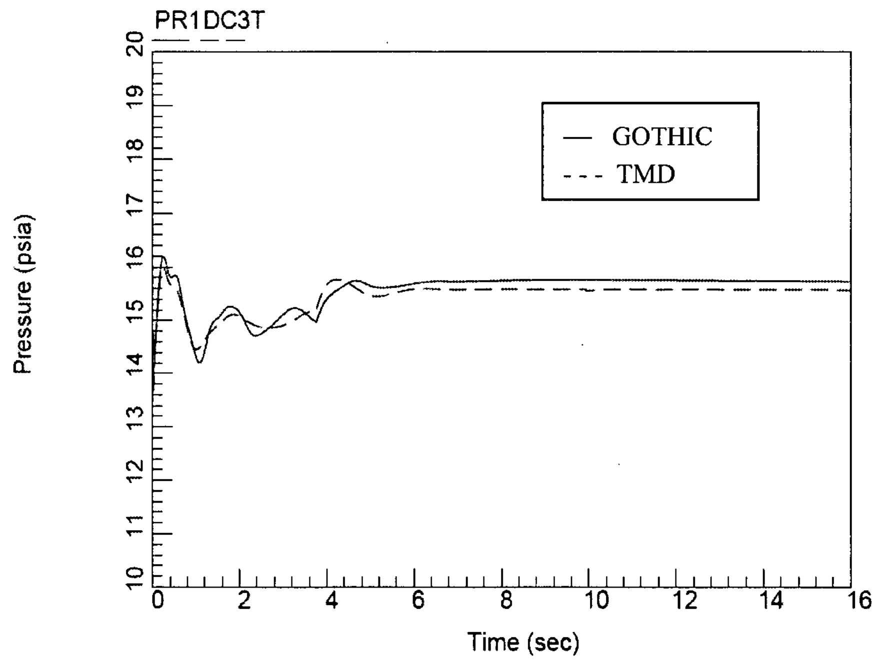

Figure 5-6 GOTHIC/TMD FWLB Pressure Comparison for [ ]a,c Calculated Volume Case without Additional Losses

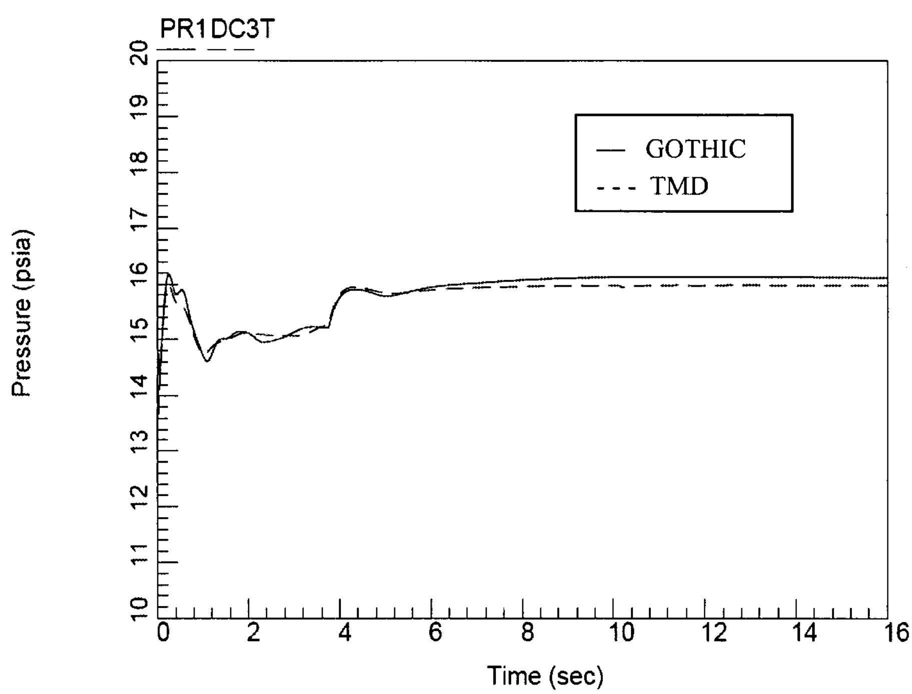

Figure 5-7 GOTHIC/TMD FWLB Pressure Comparison for [ ]a,c Calculated Volume Case with Additional Losses

6 GOTHIC SUBCOMPARTMENT MODEL DESCRIPTION AND RESULTS

A GOTHIC model representative of an ABWR steam tunnel system was analyzed to show the application of the methodology described in Section 2.

6.1 STEAM TUNNEL MODEL DESCRIPTION

The ABWR steam-tunnel is a series of corridors that house both the main steam lines (MSL) and feedwater lines (FWL) as they run from the primary containment vessel to the turbines. This series of corridors includes portions of the reactor building, control building, and turbine building. In the event of a break within the steam tunnel corridors, the steam has two pathways to the atmosphere. One pathway is through a chimney system that connects the control building/turbine building interface region to the upper turbine building, where the steam can exit through flow paths to the atmosphere. The other flow path is from the control building/turbine building interface region into the lower turbine building, which then connects to the upper turbine building. Again, the steam can then exit the upper turbine building through flow paths to the atmosphere. The GOTHIC noding diagram for the steam tunnel high energy line break (HELB) analysis is shown in Figure 6-1.

[

]a,c

Breaks are postulated to occur in the reactor building steam tunnel, the control building steam tunnel, and the lower turbine building. Main steam line break mass and energy releases for these sample analyses are calculated using the Westinghouse boiling water reactor (BWR) loss of coolant accident (LOCA) mass and energy release code GOBLIN, as described in Reference 6. Although the Reference 6 methodology for mass and energy release is not yet approved for short-term releases nor is such approval being sought with this report, it is used to demonstrate the application of the subcompartment methodology for which approval is being sought. In practice, any U.S. NRC approved BWR short-term mass and energy release methodology can be used with these models.

The feedwater line break case shown in Section 6.3 is also provided to demonstrate an application of the subcompartment methodology for a liquid line break. Because no flow occurs from the vessel, due to the presence of check valves between the break and the vessel, just the pump side of the FWLB mass and energy releases from Reference 7 are used as input for this case.

The key input data for the GOTHIC steam tunnel subcompartment model are presented in Appendix A, Table A-3.

a,c

Figure 6-1 GOTHIC ABWR Steam Tunnel Model Noding Diagram

6.2 STEAM TUNNEL MODEL RESPONSE TO A MSLB

The peak pressure for the GOTHIC steam tunnel subcompartment analysis occurs during a main steam line high energy line break located in the reactor building section of the steam tunnel. The peak pressure occurs in the reactor building section of the steam tunnel. Figure 6-2 shows the pressure response in the reactor building section of the steam tunnel. Figure 6-3 shows the pressure response for the control building section of the steam tunnel. Figure 6-4 shows the pressure response curves for the lower turbine building and the upper turbine building. The peak pressure for this steam tunnel subcompartment analysis is 23.60 psia (8.9 psig).

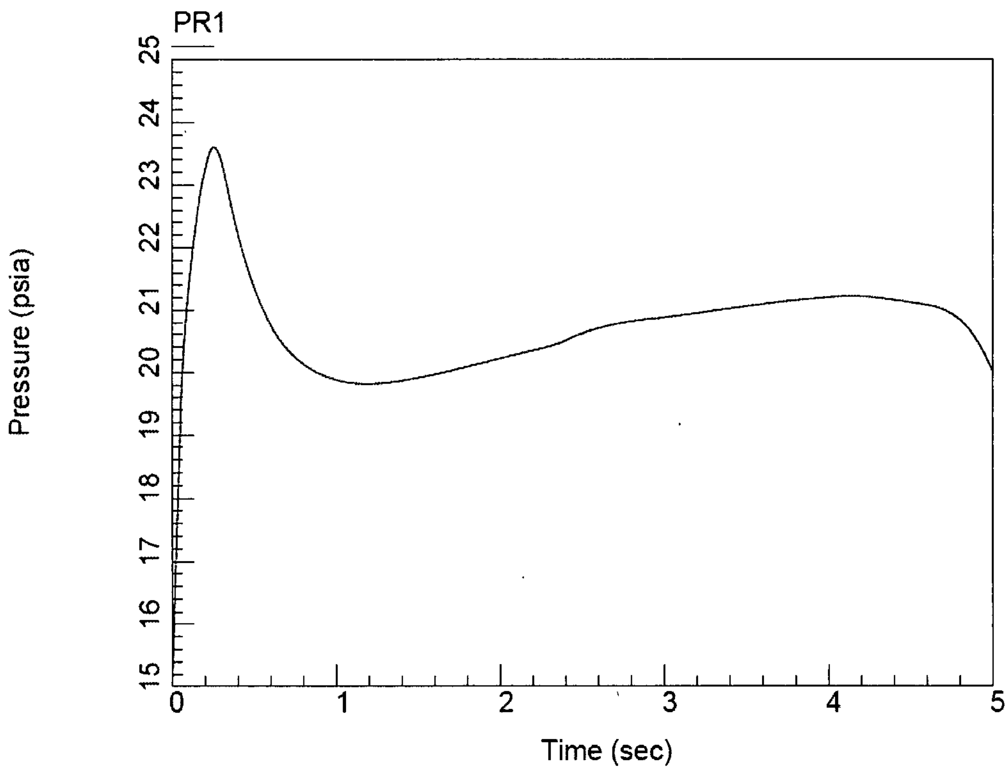

Figure 6-2 Reactor Building Pressure Response for a MSL HELB in the Reactor Building

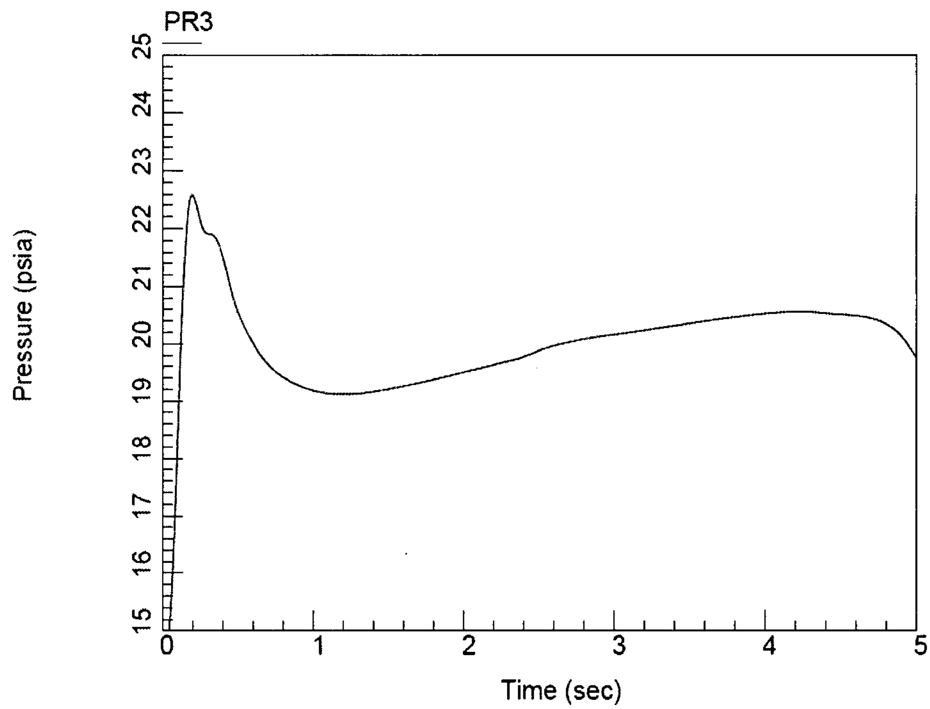

Figure 6-3 Control Building Pressure Response for a MSL HELB in the Reactor Building

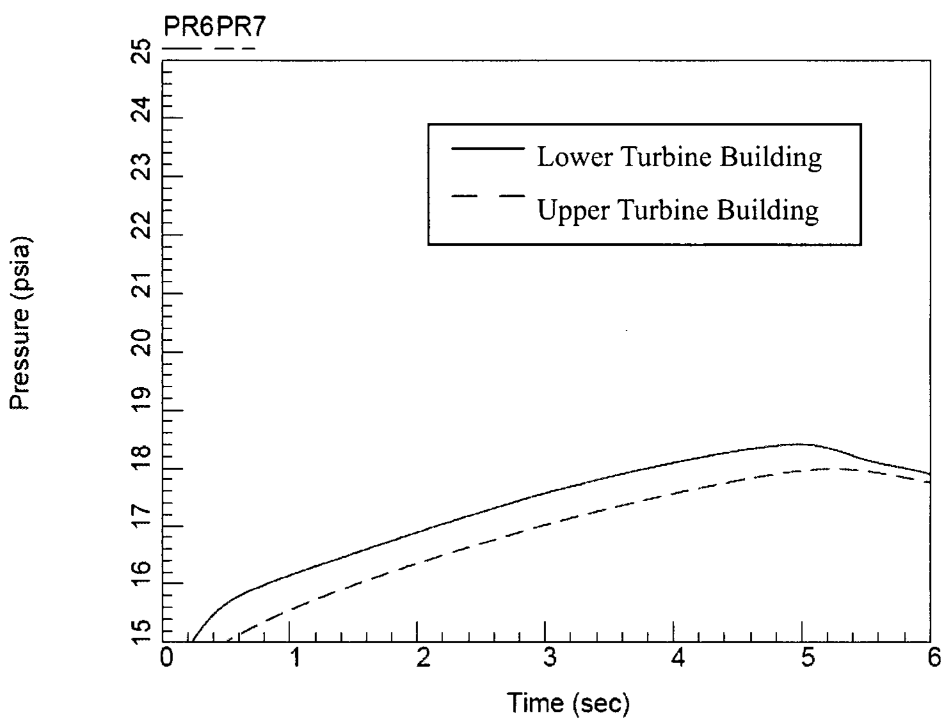

Figure 6-4 Upper and Lower Turbine Building Pressure Responses for a MSL HELB in the Reactor Building

6.3 STEAM TUNNEL MODEL RESPONSE TO A FWLB

A feedwater line break in the reactor building section of the steam tunnel was analyzed to demonstrate the behavior of the subcompartment model for a liquid line break. The calculated peak pressure in the FWLB analysis is well below the calculated peak pressure shown in the MSLB analysis. Figure 6-5 shows the pressure response in the reactor building section of the steam tunnel. The peak pressure for this steam tunnel subcompartment analysis is 17.81 psia (3.1 psig).

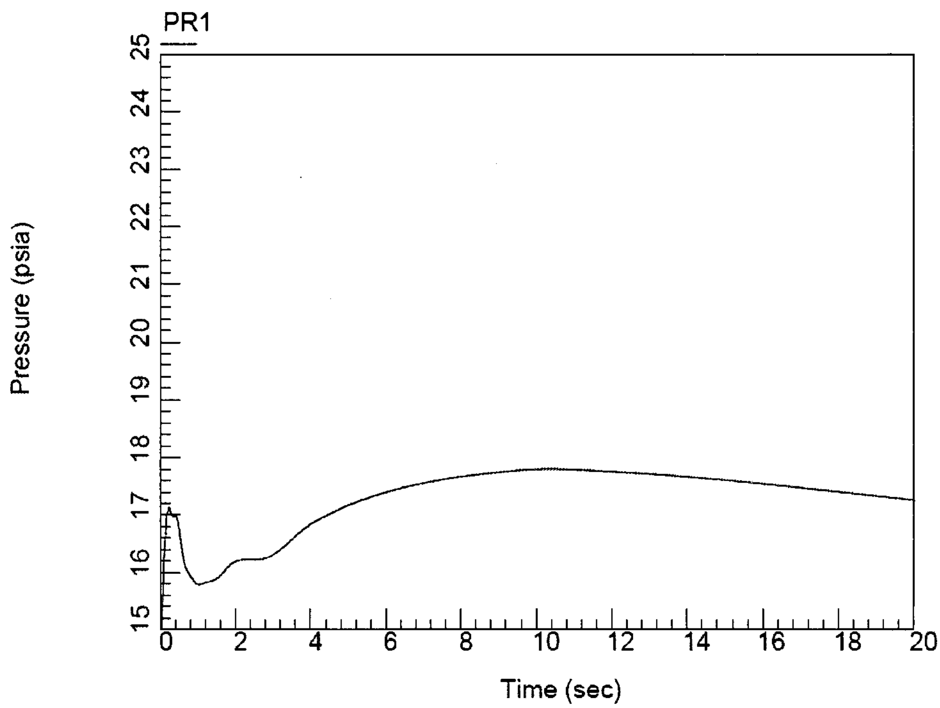

Figure 6-5 Reactor Building Pressure Response for a FWLB in the Reactor Building

6.4 STEAM TUNNEL MODEL NODING SENSITIVITY

As required by Standard Review Plan 6.2.1.2, a noding sensitivity was conducted to determine the effects of decreasing the noding size in the subcompartment analysis model. The noding sensitivity was performed for the HELB in the reactor building, which was shown to be the limiting case.

The control building section of the GOTHIC steam tunnel subcompartment model was selected for further subdivision, because it is a long corridor and may have an impact on the inertia effects observed in the model. Though the reactor building is the location of the peak pressure, it was not subdivided further for the noding sensitivity for two reasons. First, unlike the control building, which is a long narrow corridor, the reactor building is a large, open, cube-shaped volume. This open cube-shaped volume would not be subject to the same inertia effects as the control building. Second, further subdividing the volume of the break location will cause the pressure in the break node to continually increase as the node gets smaller and smaller. This will continue until the node is sufficiently small enough to act as the end of the broken pipe, and the pressure in the node will rise to the stagnation pressure of the broken pipe. This pressure is

not representative of the forces which would be seen on the subcompartment walls. For these reasons, a refined noding in the reactor building would not provide meaningful results in the noding sensitivity.

Figure 6-6 shows the noding structure used for a sensitivity case that breaks the control building section of the steam tunnel subcompartment model into two separate control volumes (Volumes 3 and 9).

a,c

Figure 6-6 Steam Tunnel 2 Volume Noding Sensitivity Noding Diagram

The calculated peak pressure for a MSLB in the reactor building section of the steam tunnel was 23.60 psia. The calculated peak pressure with the revised control building noding structure was 23.81 psia. Therefore, increasing the number of nodes in the GOTHIC steam tunnel subcompartment model resulted in a small (less than 1%) increase in the calculated peak pressure.

Next, the control building section of the steam tunnel subcompartment model was broken into five control volumes (Volumes 8, 9, 10, 11, and 12), to evaluate the impact of a further increase in the number of nodes. The noding diagram for this sensitivity case is shown in Figure 6-7.

a,c

Figure 6-7 Steam Tunnel 5 Volume Noding Sensitivity Noding Diagram

The calculated peak pressure with this more detailed noding structure was 23.87 psia. This is only a 1.1% increase relative to the base case, and only a 0.25% increase relative to the two node variation. These small pressure changes are insignificant relative to the excess pressure due to the model conservatisms and the base case noding is judged acceptable.

7 CONCLUSIONS

A new analysis code/methodology is required to perform future ABWR subcompartment design analyses. The GOTHIC code has been selected to perform these analyses.

This Licensing Topical Report provides a description of the methodology intended to be used to perform the ABWR subcompartment design analyses with GOTHIC. The methodology is consistent with the SRP requirements listed in Section 6.2.1.2 of NUREG-0800.

The GOTHIC code qualification report (Reference 4) provides a comparison of the code results to subcompartment test data. The good comparison that is presented in the report demonstrates that the code contains the required modeling capabilities needed to perform ABWR subcompartment design analyses.

A benchmark transient comparison with the U.S. NRC approved subcompartment analysis code TMD further qualifies the application of the GOTHIC subcompartment design analysis methodology for the ABWR. The GOTHIC model results compare very well to the TMD benchmark analysis results.

The first application of this new subcompartment design analysis methodology is expected to be for the ABWR._The results from a representative GOTHIC ABWR steam tunnel model are provided to demonstrate the application of the methodology for the ABWR.

8 REFERENCES

1. AEC-TR-6630, "Handbook of Hydraulic Resistance-Coefficients of Local Resistance and of Friction," Idel'chik, 1966.

2. WCAP-8077, "Ice Condenser Containment Pressure Transient Analysis Methods," March 1973.

3. U.S. ABWR Design Control Document, GE Nuclear Energy, Revision 4, March 1997.

4. NAI 8907-09, Rev. 9, "GOTHIC Containment Analysis Package Qualification Report," Version 7.2a (QA), January 2006.

5. NUREG-800, "U.S. Nuclear Regulator Commission Standard Review Plan – 6.2.1.2 Subcompartment Analysis," March 2007.

6. WCAP-16608-P-A, Appendix B, "Westinghouse Containment Methodology," March 2009.

7. WCAP-17058, "Implementation of ABWR DCD Methodology using GOTHIC for STP 3 and 4 Containment Design Analyses," June 2009.

APPENDIX A
INPUT TABLES

Table A-1 DCD Volume Benchmark Input Table

a,c

Table A-1 (cont.) DCD Volume Benchmark Input Table

a,c

Table A-2 Calculated Volume Benchmark Input Table

a,c

Table A-2 (cont.) Calculated Volume Benchmark Input Table

a,c

Table A-3 Steam Tunnel Analysis Model Input Table

a,c

Table A-3 Steam Tunnel Analysis Model Input Table (cont.)

a,c

APPENDIX B
NRC RAI'S AND WESTINGHOUSE RESPONSES

RAI-1

QUESTION:

In order to perform subcompartment confirmatory analyses, please provide both mass and energy release rates data and the complete list of geometrical data used in the GOTHIC analysis, including the list of all of the thermal-hydraulic options used in the STP ABWR analysis. A copy of the GOTHIC input used for the sub-compartment licensing calculations is also being requested.

RESPONSE:

The mass and energy release rate data used in the GOTHIC analysis are provided in the enclosed CD titled "Mass and Energy Release Data for RAI-1 WCAP-17065". The data in this CD are proprietary.

The geometrical data used in the GOTHIC analysis are provided in Appendix A to WCAP-17065. These include such steam tunnel parameters as: volumes, heights, and base elevations. These also include such vent path parameters as: flow areas, hydraulic diameters, and inertial lengths. This represents all of the relevant geometrical data that would be needed to perform a subcompartment confirmatory analysis.

The thermal-hydraulic options such as choked flow modeling, compressibility, drop-to-liquid conversion, and drop size, which would be needed to perform a confirmatory analysis, are also provided in Appendix A to WCAP-17065.

The GOTHIC subcompartment calculations in support of WCAP-17065, which would include all of the GOTHIC input used for the sub-compartment licensing calculations, can be made available in the Westinghouse Reading Room for NRC review.

RAI-2

QUESTION:

The April 29, 2010, Topical Report for ABWR subcompartment analysis discusses the use of GOTHIC and the subcompartment methodology for plants other than ABWR. For example , Section 7.0 Conclusions discusses "The first application of this new subcompartment design analysis methodology is expected to be for the ABWR; however this methodology could be used for subcompartment design analyses for any plant." The application of this methodology has not been justified for plants other than the ABWR.

Please revise the April 29, 2010 Topical Report to make clear that it is only applicable to subcompartment analysis for ABWR.

RESPONSE:

The April 29, 2010 Topical Report, WCAP-17065-P Revision 0, titled "Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC", is requesting NRC approval to apply the GOTHIC methodology for subcompartment analysis for only the ABWR.

In response to this RAI, WCAP-17065-P will be revised as shown in the markup below of Revision 0 of that report with gray shading highlighting the changes.

1 INTRODUCTION AND BACKGROUND

A subcompartment design analysis methodology that uses the GOTHIC code is described in this report. Westinghouse is planning to use GOTHIC for future containment analysis work. Using a single code for containment analyses will simplify code maintenance and user qualification activities. Furthermore, TMD has modeling limitations that do not exist in GOTHIC.

The GOTHIC code qualification report (Reference 4) compares model results to a number of tests that represent conditions similar to those that would be observed in a typical subcompartment analysis. This provides a significant level of confidence that GOTHIC is a suitable tool for performing subcompartment analyses. To provide an additional level of confidence, Westinghouse performed a benchmark comparison to the approved TMD subcompartment analysis methodology using GOTHIC and TMD models of the ABWR steam tunnel subcompartment configuration that is described in the ABWR DCD.

The purpose of this report is to document and demonstrate the Westinghouse implementation of the GOTHIC subcompartment analysis methodology for the ABWR. This document provides:

7 CONCLUSIONS

A new analysis code/methodology is required to perform future ABWR subcompartment design analyses. The GOTHIC code has been selected to perform these analyses.

This Licensing Topical Report provides a description of the methodology intended to be used to perform the ABWR subcompartment design analyses with GOTHIC. The methodology is consistent with the SRP requirements listed in Section 6.2.1.2 of NUREG-0800.

The GOTHIC code qualification report (Reference 4) provides a comparison of the code results to subcompartment test data. The good comparison that is presented in the report demonstrates that the code contains the required modeling capabilities needed to perform subcompartment design analyses.

A benchmark transient comparison with the U.S. NRC approved subcompartment analysis code TMD further qualifies the application of the GOTHIC subcompartment design analysis methodology. The GOTHIC model results compare very well to the TMD benchmark analysis results.

The first application of this new subcompartment design analysis methodology is expected to be for the ABWR~~; however, this methodology could be used for subcompartment design analyses for any plant~~. The results from a representative GOTHIC ABWR steam tunnel model are provided to demonstrate the application of the methodology for the ABWR.

RAI-3:

QUESTION:

In RAI 1 the staff requested that the applicant provide Mass and Energy Data that was created using GOBLIN. However, the data provided in response to the RAI was unlabeled. Please provide labels and units as well as a description for the case each tab represents.

RESPONSE:

The GOBLIN-created mass and energy release rate data, with the labels, units and case descriptions identified as requested, are provided in the file titled "Copy of gothic m_e data (2).xls" which is included on the enclosed CD titled "M&E Release Data and GOTHIC Input Deck for RAI's 3 and 5 to WCAP-17065". Two sets of mass flow rate and enthalpy flow data are provided for each case, because, for a double-ended break, there will be flow from both sides of the break. The data in this CD are proprietary to Westinghouse.

RAI-4

QUESTION:

SRP 6.2.1.2 requires that a nodalization sensitivity study be performed so that there is no substantial pressure gradient within a node. The applicant chose to perform a sensitivity study on the control structure building steam tunnel. In order for the staff to verify that the nodalization sensitivity study was in accordance with guidance 1) the current sensitivity study should be further performed to verify that the pressure increases will eventually converge to an upper limit and 2) perform a second sensitivity study in the reactor building steam tunnel to support the applicant's conclusion that volume would not be subject to the same inertia effects as the control structure building steam tunnel and that the pressure in the room would eventually reach the stagnation pressure of the broken pipe.

RESPONSE:

1) In order to address the first item, the current sensitivity study was expanded to verify that the pressure increases will eventually converge to an upper limit. Two noding sensitivity studies were performed in addition to those performed in Reference 1. Table 4-1 shows the impact on peak pressure of increasing the number of nodes in the control building. The peak pressures show convergence near the 8 to 10 node range.

Table 4-1 Peak Pressure as a Function of Number of Nodes

Number of Nodes	Peak Pressure (psia)
1	23.60
2	23.81
5	23.87
8	23.90
10	23.90

2) A noding sensitivity study was performed on the reactor building steam tunnel. In addition to the lumped volume case, the analysis was performed for node cases of 3, 5 and 10 in the break node of the reactor building steam tunnel. The results show that the inertia effects in the reactor building steam tunnel are comparable to those seen in the control building sensitivity studies. The reactor building steam tunnel noding study found that a pressure wave exists that results in pressure oscillations throughout the various nodes used in the study. These oscillations produce localized pressure changes based on the location of the wave and size of the node; therefore, they do not represent the average pressure observed along the entire length of the walls in the reactor building tunnel, which is the pressure sought in these analyses. The reported pressure for the reactor building portion of the tunnel is based on the midpoint of the pressure waves observed in GOTHIC, and converges to a pressure of around 23.8 psia for the 5 and 10 node cases. This pressure is lower than that

observed in the control building steam tunnel sensitivities, which converges to a pressure of 23.9 psia.

Additional studies were performed 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 was performed in GOTHIC using the Control Volume > Subdivide feature. Two sensitivity studies were performed to show the impact of this, and the pressures in the break node were on the order of several hundred psi for both cases.

The calculation which was performed to support this response is available for NRC review.

Reference

1. WCAP-17065-P, "Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC," April 2010.

RAI-5

QUESTION:

In order for the NRC staff to perform their audit calculations, they require that the applicant submit their GOTHIC input deck. This will supplement the NRC staff in reviewing the applicant's nodalization sensitivity study and the pressure transients in the model.

RESPONSE:

The GOTHIC input deck is provided in two of the files which are included in the attached CD titled "M&E Release Data and GOTHIC Input Deck for RAI's 3 and 5 to WCAP-17065". The file names are:

File 1: DCDVol_DCDMEs_WithAddlLosses.GTH_1290449229_LTR-CRA-10-239

File 2: RB_Analy_TB_FP_NEWME.GTH_1290449230_LTR-CRA-10-239

The data in this CD are proprietary to Westinghouse.

Please note that the mass and energy releases in the STP representative steam tunnel analysis model use a Westinghouse computer program. In order to run this model outside of Westinghouse, it will be necessary to update the break release boundary conditions to use tables containing the reactor building mass and energy releases provided in the response to RAI-3 to WCAP-17065.

RAI-6

QUESTION

In Appendix A of the applicant's report on the ABWR subcompartment methodology using GOTHIC, the applicant provides input data. The applicant should confirm which case Table A-1, Table A-2; and Table A-3 correspond to in the applicant's analysis. The staff noted that the forward and reverse loss coefficients change with each case. Please explain the discrepancy between the ABWR DCD loss coefficients and the cases provided in Table A-1, Table A-2, and Table A-3. Also provide an explanation for how the applicant arrived at the values it used for each volume in the analysis for each case in Table A-1, Table A-2, and Table A-3 and the relationship to the volume data provided in the ABWR DCD.

RESPONSE

Table A-1, "DCD Volume Benchmark Input Table" provides the input data to the "DCD Volume Model" described in Reference 1, Section 5, Item 1. Note that a typographical error was discovered in that item description. The text should read "These models are based on the volume data provided in the DCD. DCD flow path loss coefficients are used for flow paths including the additional mechanical losses given in the DCD." Therefore, the word "without" should be removed from the second sentence in this bullet. Reference 1 will be revised to correct this typographical error.

Table A-2, "Calculated Volume Benchmark Input Table" provides the input data to the "80% Calculated Volume Model with Additional Losses" described in Reference 1, Section 5, Item 3. Table A-2 also provides the input data to the "80% Calculated Volume Model without Additional Losses" described in Reference 1, Section 5, Item 2, except that the loss coefficients are reduced by 1.7 for the following vent paths: CBST to TBST1, TBST1 to TBST2, CBST to TB, and TBST2 to TB.

Table A-3, "Steam Tunnel Analysis Model Input Table" provides the input data to the Reference 1, Section 6 representative steam tunnel analysis model.

The loss coefficients used in the ABWR DCD subcompartment analysis are shown in Tier 2, Table 6.2-4 of the ABWR DCD. In addition, Table 6.2-4a indicates that an additional "Mechanical Loss Coefficient" is used to account for the losses in some rooms for the ABWR DCD analysis. These loss coefficients, which are defined in the ABWR DCD, are used as the form losses for the Table A-1 Model (DCD Volume Benchmark) and the Table A-2 Models (80% Calculated Volume Benchmarks). Because the values in the ABWR DCD are only considered to be form losses, the Table A-1 and Table A-2 loss coefficients must then be increased to account for friction losses using Equation 2-3 of Reference 1. This is why the loss coefficients shown in the ABWR DCD do not exactly match the Table A-1 and Table A-2 values.

The loss coefficients in Table A-1 differ from those in Table A-2 due to a difference in the equivalent lengths used in the friction loss calculations for the analyses applicable to those tables. Because the room volumes change from Table A-1 to Table A-2, the corresponding flow areas

also change. This change in flow areas causes a change to the inputs used in the equivalent length calculation, which is shown as Equation 2-4 of Reference 1. This accounts for the small difference between the ABWR DCD loss coefficients and those used for the benchmark analyses.

Because the representative steam tunnel configuration used in Section 6 of Reference 1 is different from that used in the ABWR DCD analyses, the loss coefficients in the ABWR DCD are not used. Instead, new loss coefficients were calculated using the approach defined in Section 2.3 of Reference 1.

The room volume input used in the Table A-1 model (DCD Volume Benchmark) is the same as that used in Table 6.2-3 of the ABWR DCD. The volumes used in the Table A-2 models (80% Calculated Volume Benchmark) were calculated by scaling the dimensions from available ABWR DCD drawings. The volumes used in the representative steam tunnel model are based on preliminary drawings of the representative steam tunnel and turbine building.

Reference

1. WCAP-17065-P, "Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC," April 2010.

RAI-6 Supplement 1

QUESTION:

In Appendix A of the applicant's report on the ABWR subcompartment methodology using GOTHIC, the applicant provides input data. The applicant should confirm which case Table A-1, Table A-2; and Table A-3 correspond to in the applicant's analysis. The staff noted that the forward and reverse loss coefficients change with each case. Please explain the discrepancy between the ABWR DCD loss coefficients and the cases provided in Table A-1, Table A-2, and Table A-3. Also provide an explanation for how the applicant arrived at the values it used for each volume in the analysis for each case in Table A-1, Table A-2, and Table A-3 and the relationship to the volume data provided in the ABWR DCD.

SUPPLEMENTAL RESPONSE:

The original response to this RAI was transmitted to the NRC in STPNOC Letter No. U7-C-NINA-NRC-110003 dated January 31, 2011. In that response, it was noted that a typographical error was discovered in Section 5, List Item 1 in WCAP-17065-P in which the word "without" should be removed from the second sentence in the Item 1 description. However, no markup of WCAP-17065-P was provided in that response. This supplemental response provides that markup with gray shading showing the change from Rev 0 of WCAP-17065-P.

WCAP-17065-P Markup

5 GOTHIC BENCHMARK MODEL DESCRIPTION AND RESULTS

1. DCD Volume Model – These models are based on the volume data provided in the DCD. DCD flow path loss coefficients are used for flow paths ~~without~~ including the additional mechanical losses given in the DCD.

RAI-7

QUESTION:

The applicant benchmarked the GOTHIC subcompartment methodology against the ABWR DCD subcompartment analysis in Section 5. However, the applicant does not explain the differences observed between the ABWR DCD results and those in GOTHIC. Please explain the possible differences that could be causing the variation in pressure trends and peak pressure time.

RESPONSE:

The differences between the GOTHIC benchmark results and the ABWR DCD results can only be explained based on engineering judgment, because Westinghouse does not have access to the DCD analyses, which were performed by GE. It is judged that the primary reason for the difference in results is the treatment of inertia in GOTHIC versus the GE SCAM code, which was used in the ABWR DCD. SCAM is an older code, which is limited in its capability to address inertia. It is believed that the ABWR DCD analyses attempted to account for inertia using higher loss coefficients. In GOTHIC, the inertia length is explicitly modeled. Informal sensitivity studies have shown that, when inertia is not considered, GOTHIC compares favorably with the ABWR DCD results.

RAI-8

QUESTION:

During an audit of STP's topical report on ABWR subcompartment analysis using GOTHIC the NRC staff identified areas which required clarification. The staff requests that the applicant specify the following information:

1.) Please clarify in the report specifically what approval is being sought; and what, if any, limitations are considered appropriate. Please address, at a minimum, the general scope of the approval with respect to breaks, break locations, correlations and loss coefficients and the role of the currently unapproved mass and energy release code reference in the report.

2.) Please specify what version of the GOTHIC code is being used for this specific application?

3.) Please describe the procurement methodology for GOTHIC.

   a. Is it procured as safety related?

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

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

RESPONSE:

1. Westinghouse will update the topical report to clearly address the scope and limitations for the approval being sought. In addition, the report will be updated to address the use of the GOBLIN code to generate the required ABWR short-term mass and energy release input for the subcompartment pressurization analyses. This update will be provided by January 15, 2011.

2. Westinghouse is currently using GOTHIC version 7.2a for the ABWR subcompartment analyses.

3. Westinghouse is a member of the EPRI GOTHIC Advisory Group and receives copies of the GOTHIC code from Numerical Applications Incorporated (NAI). NAI is a Westinghouse-qualified software vendor and the GOTHIC code is procured as a safety-related component. The computer software used in engineering applications is governed by procedures and processes established in accordance with the Westinghouse Quality Management System (QMS). Westinghouse software QA procedures control the installation, configuration control, notification, and resolution of errors for software obtained from qualified software vendors. These procedures are in compliance with, and address the requirements of 10 CFR 50 Appendix B and 10 CFR Part 21. In addition, the development and maintenance of the GOTHIC code by NAI is done under the requirements of 10 CFR 50, Appendix B and 10 CFR Part 21, as verified by Westinghouse through periodic quality assurance reviews of qualified software vendors.

RAI-8 Supplement 1

QUESTION:

During an audit of STP's topical report on ABWR subcompartment analysis using GOTHIC the NRC staff identified areas which required clarification. The staff requests that the applicant specify the following information:

1.) Please clarify in the report specifically what approval is being sought; and what, if any, limitations are considered appropriate. Please address, at a minimum, the general scope of the approval with respect to breaks, break locations, correlations and loss coefficients and the role of the currently unapproved mass and energy release code reference in the report.
2.) Please specify what version of the GOTHIC code is being used for this specific application?
3.) Please describe the procurement methodology for GOTHIC.
    a. Is it procured as safety related?
    b. Was it developed under a program meeting 10 CFR 50, Appendix B and 10 CRF Part 21?
    c. Describe the procurement chain for Qualification of NAI as an Appendix B supplier.

SUPPLEMENTAL RESPONSE:

The original response to this RAI was transmitted to the NRC in STPNOC Letter No. U7-C-STP-NRC-100261 dated December 28, 2010. In that response, it was noted that Westinghouse will update WCAP-17065-P to clearly address the scope and limitations for the approval being sought. In addition, the report would be updated to address the use of the GOBLIN code to generate the required ABWR short-term mass and energy release input for the subcompartment pressurization analyses. This supplemental response provides the markup to address these items with gray shading showing the change from Rev 0 of WCAP-17065-P.

WCAP-17065-P Markups

1 INTRODUCTION AND BACKGROUND

The code that was used by General Electric (GE) to perform the ABWR subcompartment design analyses for the design control document (DCD) (Reference 3) is not available to Westinghouse or Toshiba. Therefore, an alternative code/methodology is required to address potential future ABWR design changes.

An ABWR subcompartment design analysis methodology that uses the GOTHIC code is described in this report. Westinghouse is planning to use GOTHIC for future containment analysis work. Using a single code for containment analyses will simplify code maintenance and user qualification activities. Furthermore, TMD has modeling limitations that do not exist in GOTHIC.

The GOTHIC code qualification report (Reference 4) compares model results to a number of tests that represent conditions similar to those that would be observed in a typical subcompartment analysis. This provides a significant level of confidence that GOTHIC is a suitable tool for performing subcompartment analyses. To provide an additional level of confidence, Westinghouse performed a benchmark comparison to the approved TMD subcompartment analysis methodology using GOTHIC and TMD models of the ABWR steam tunnel subcompartment configuration that is described in the ABWR DCD.

The purpose of this report is to ~~document and~~ ~~demonstrate~~ obtain NRC approval for the Westinghouse implementation of the GOTHIC subcompartment analysis methodology for the ABWR as described in Section 2 of this report. This methodology will be used to analyze breaks located in subcompartments outside of the primary containment (i.e. secondary containment and the steam tunnel system). This document provides:

2 SUBCOMPARTMENT MODELING METHODOLOGY

This section describes the ABWR subcompartment modeling methodology for which approval is being sought. This section describes the input development method to be used for Westinghouse ABWR subcompartment analyses.

2.1 CONTROL VOLUMES

6.1 STEAM TUNNEL MODEL DESCRIPTION

Breaks are postulated to occur in the reactor building steam tunnel, the control building steam tunnel, and the lower turbine building. Main steam line break ~~M~~mass and energy releases for these sample analyses are calculated using the Westinghouse boiling water reactor (BWR) loss of coolant accident (LOCA) mass and energy release code GOBLIN, as described in Reference 6. Although the Reference 6 methodology for mass and energy release is not yet approved for short-term releases nor is such approval being sought with this report, it is used to demonstrate the application of the subcompartment methodology for which approval is being sought. In practice, any USNRC approved BWR short-term mass and energy release methodology can be used with these models.

The feedwater line break case shown in Section 6.3 is also provided to demonstrate an application of the subcompartment methodology for a liquid line break. Because no flow occurs from the vessel, due to the presence of check valves between the break and the vessel, just the pump side of the FWLB mass and energy releases from Reference 7 are used as input for this case.

7 CONCLUSIONS

The GOTHIC code qualification report (Reference 4) provides a comparison of the code results to subcompartment test data. The good comparison that is presented in the report demonstrates that the code contains the required modeling capabilities needed to perform ABWR subcompartment design analyses.

A benchmark transient comparison with the U.S. NRC approved subcompartment analysis code TMD further qualifies the application of the GOTHIC subcompartment design analysis methodology for the ABWR. The GOTHIC model results compare very well to the TMD benchmark analysis results.

RAI-9

QUESTION:

The applicant provides an inertia length equation (equation 2-2) in the topical report on ABWR subcompartment analysis using GOTHIC which is calculated in accordance with GOTHIC. During the audit it was identified that this was derived as a best estimate approach and may not represent an appropriate level of conservatism for design basis accident analysis. Please justify the use of the GOTHIC inertia length (equation 2-2) as a conservative assumption. Further please clarify the use of this equation with respect to the validation and verification of the GOTHIC code and justify the continued relevance of the V&V report with respect to this inertial length equation and the submitted topical report.

RESPONSE:

The inertia length equation (Equation 2-2 of WCAP-17065-P) gives the best estimate inertia in GOTHIC for a flow path connecting two lumped volumes. The formula was developed by comparing lumped modeling and computational fluid dynamics (CFD) modeling results for the transient response of single phase flow through an opening between two rooms due to an initial pressure differential across the opening. Various connection geometries were considered including an orifice, an expansion, and a contraction. The ratio of the opening to room size was also varied. Both 2D and 3D meshes were used for the CFD analysis. The resulting formula (Equation 2-2) represents a best estimate fit over all the cases considered. For all cases considered, the inertia length from Equation 2-2 is within [ ][a,c] of the effective inertia length from the CFD analysis.

The inertia equation also provides a consistent approach to handling geometries in which a small room connects to a very large room (such as the turbine building), or to the atmosphere. In these cases, it can be difficult to determine a suitable inertia length using the center-to-center approach, which was the previously recommended value used in the GOTHIC Qualification Report (NAI 8807-09), because the center-to-center assumption produces an unrealistically high inertia length. In these cases, it has been common practice to use twice the upstream volume inertia length to produce a more reasonable inertia value; however, this may lead to a lower than reasonable inertia length based on the upstream volume characteristics. By using Equation 2-2, connections between large and small volumes are handled in a consistent manner.

As noted earlier, the inertia lengths for the models in the GOTHIC Qualification Report use the room center-to-center distance. In response to this RAI, several of the models for tests in which room-to-room pressure differentials were measured were revised using inertia lengths from Equation 2-2. Specifically, the models for tests D-1, D-15, and D-16 from the Battelle Frankfurt Model Containment (BFMC) and test V21.1 from the Heissdampfreaktor (HDR) facility were revised. Results from these tests are shown below.

Attachment 9-1 to this RAI shows the GOTHIC modeling, a comparison of the calculated inertia lengths for the center-to-center and the Equation 2-2 methods, and the time-dependent room-to-

room differential pressure using inertia lengths calculated by these two methods for the D-1 test. Also provided are comparisons of the calculated differential pressures with the test results using both methods. The result of those comparisons shows that the differential pressures are not significantly different using inertia lengths calculated with the two methods, and the same test points are bounded by both methods.

Attachments 9-2, 9-3 and 9-4 show the same information as Attachment 9-1 but for the D-15, D-16 and HDR tests, respectively. Again, the result shows that the differential pressures are not significantly different using inertia lengths calculated using the two methods, and the same test points are also bounded by both methods.

Attachment 9-5 shows the ratios of the inertia lengths and peak differential pressures as well as the time of peak differential pressure using the two methods for Tests D-1, D-15, D-16 and HDR. This further shows that both the peak differential pressure and the time at which the peak differential pressure occurs are not greatly affected by use of the inertia length calculated using Equation 2-2 versus the room center-to-center distance.

In summary, although the inertia lengths from Equation 2-2 are [ ]^{a,c} the room center-to- center distance used in the Qualification Report, the peak differential pressures are not overly sensitive to the inertia length. Also, the same test data points of differential pressure are bounded using the two methods, which demonstrates that use of the inertia length using Equation 2-2 is comparably conservative to the center-to-center approach, and the previous validation and verification of GOTHIC is also valid for the calculation of inertia length using Equation 2-2. For the main steam line break, which represents the limiting break resulting in the highest peak pressures as shown in WCAP-17065-P, the calculated peak pressures using both methods bound the test data (see the comparison figures for tests D-1 and D-15 below) In addition, as opposed to the previously recommended room center-to-center value for determining inertia lengths, Equation 2-2 provides a uniform method of calculating the inertia length between rooms, independent of the geometry being modeled.

It is important to note that although inertia length is calculated as a realistic best estimate value, the overall secondary containment model remains conservative. This is due to other conservatisms added to the model, such as reduced air space volume in the rooms, reduced flow areas for the junctions, treatment of the break flow and the treatment of droplets at the break discharge.

Battelle-Frankfurt Test D-1 Result Comparison

Battelle-Frankfurt test D-1 is a steam blowdown experiment that was conducted in the Battelle-Frankfurt Model Containment (BFMC) test facility. The primary interest in this test is the time period immediately following blowdown when differential pressures between rooms are highest. A schematic of the GOTHIC model for this test is shown in Figure 4-1.

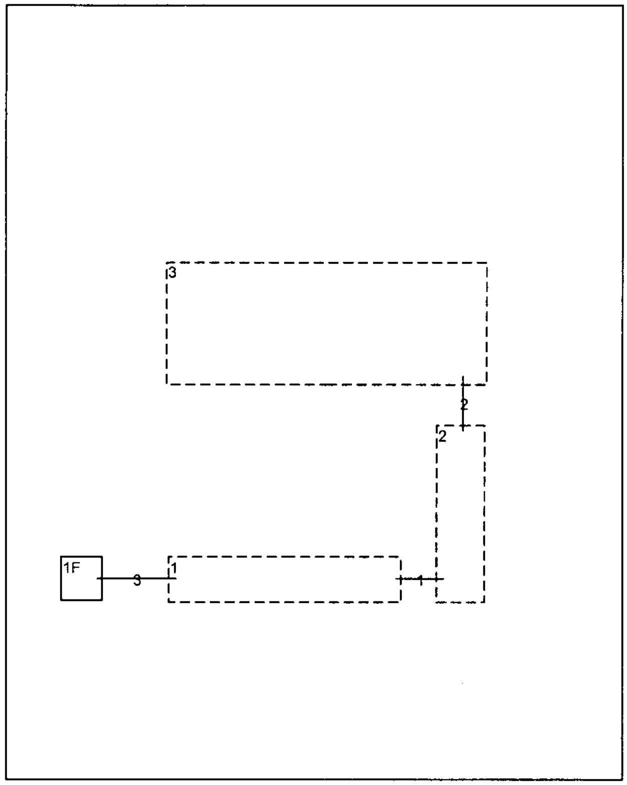

Figure 4-1 GOTHIC Model for BFMC Test D-1

In this model, the break location is room 6 (lumped volume #1). The break flow is all steam and is represented by flow boundary condition 1F and flow path #3. The inertia lengths for flow path #1 and flow path #2 have been re-calculated using Equation 2-2. Table 4-1 shows the "C2C" inertia length (based on center-to-center distance) and the "Equ 2-2" inertia length (based on using Equation 2-2 of WCAP-17065-P) for flow paths #1 and #2.

Table 4-1 C2C and Equ 2-2 Inertia Lengths for BFMC Test D-1

Flow Path	C2C	Equ 2-2
Flow Path #1	5.34	[ ]a,c
Flow Path #2	10	[ ]a,c

The C2C and Equ 2-2 differential pressures between rooms R6 (lumped volume #1) and R4 (lumped volume #2) are shown in Figure 4-2 and Figure 4-3, respectively.

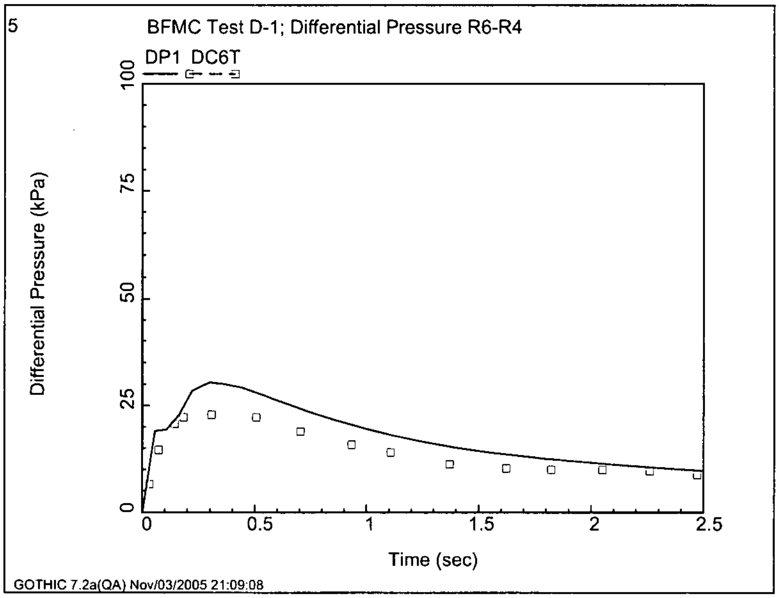

Figure 4-2 BFMC D-1, C2C Differential Pressure between Room R6 and R4

a,c

[ ]

Figure 4-3 BFMC D-1, Equ 2-2 Differential Pressure between Rooms R6 and R4

[

]a,c

Figure 4-4 and Figure 4-5 show the C2C and Equ 2-2 differential pressure between room 4 and room 9. [

][a,c]

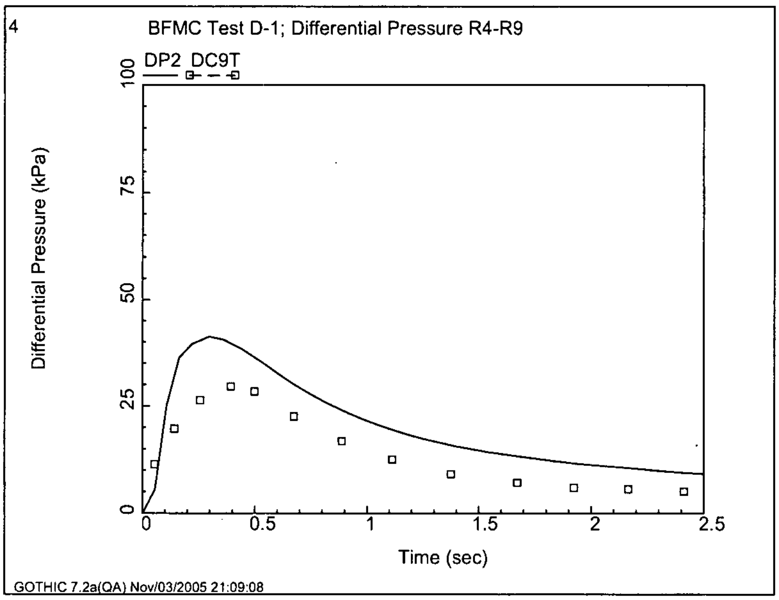

Figure 4-4 BFMC D-1, C2C Differential Pressure between Rooms R4 and R9

a,c

Figure 4-5 BFMC D-1, Equ 2-2 Differential Pressure between Rooms R4 and R9

Figure 4-6 and Figure 4-7 show the C2C and Equ 2-2 differential pressure between room 6 and room 9. [

][a,c]

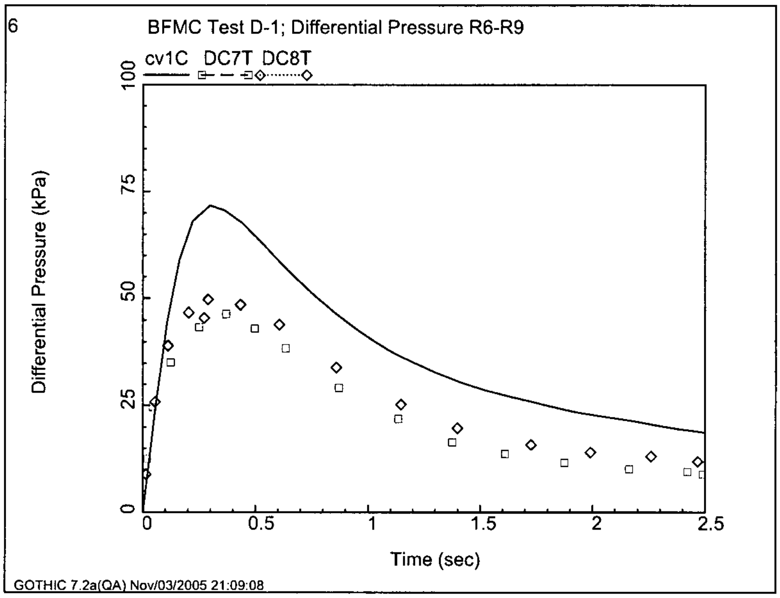

Figure 4-6 BFMC D-1, C2C Differential Pressure between Rooms R6 and R9

a,c

Figure 4-7 BFMC D-1, Equ 2-2 Differential Pressure between Rooms R6 and R9

Battelle-Frankfurt Test D-15 Result Comparison

Battelle-Frankfurt test D-15 is, in many respects, similar to test D-1. The primary interest in the test was to measure the differential pressures across internal walls in the time period immediately following blowdown, when the differential pressures between the rooms are highest. The

differential pressures create forces on internal walls of a containment that could lead to structural failure. A schematic of the GOTHIC model for this test is shown in Figure 4-8.

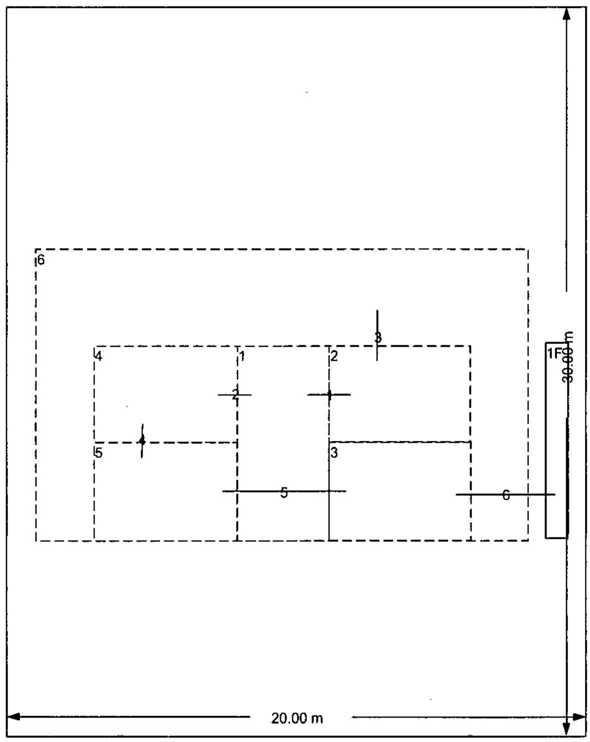

Figure 4-8 GOTHIC Model for BFMC Test D-15

In this test, the break location is in room 6 (lumped volume #3). The break flow is represented by flow boundary condition 1F. Inertia lengths of flow paths 1 through 5 have been re-calculated using the GOTHIC recommended formula of Equation 2-2. Table 4-2 shows a list of C2C and Equ 2-2 values for inertia length for flow paths 1 through 5.

Table 4-2 C2C and Equ 2-2 Inertia Lengths for BFMC Test D-15

Flow Path	**C2C**	**Equ 2-2**
Flow Path #1	5.34	[ ] a,c
Flow Path #2	5.34	[ ] a,c
Flow Path #3	3.00	[ ] a,c
Flow Path #4	3.00	[ ] a,c
Flow Path #5	10.00	[ ] a,c

Figure 4-9 and Figure 4-10 show the C2C and Equ 2-2 differential pressure between room 5 and room 9.

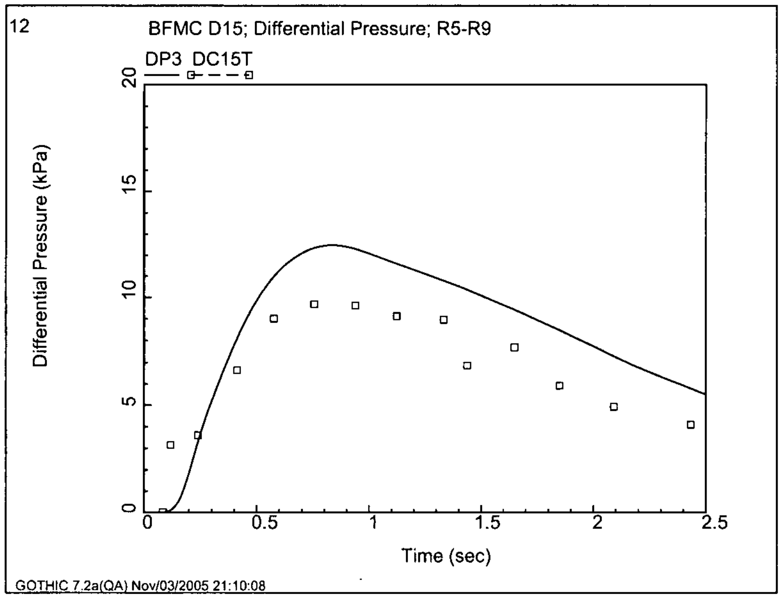

Figure 4-9 BFMC D-15, C2C Differential Pressure between Rooms R5 and R9

a,c

[

]

Figure 4-10 BFMC D-15, Equ 2-2 Differential Pressure between Rooms R5 and R9

[

]^{a,c}

Figure 4-11 and Figure 4-12 show the differential pressure between room 7 and 8.

[

]^{a,c}

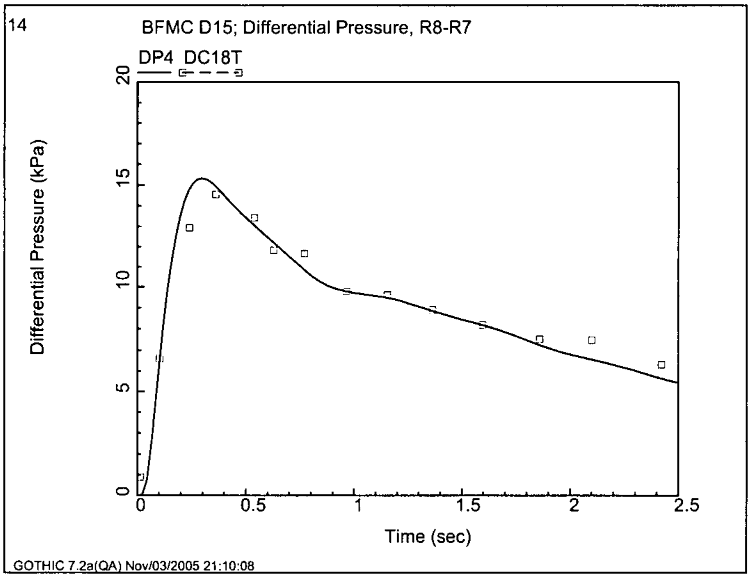

Figure 4-11 BFMC D-15, C2C Differential Pressure between Rooms R8 and R7

a,c

[ ]

Figure 4-12 BFMC D-15, Equ 2-2 Differential Pressure between Rooms R8 and R7

Figure 4-13 and Figure 4-14 show the C2C and Equ 2-2 differential pressures between room 6 and room 9.

[

]a,c

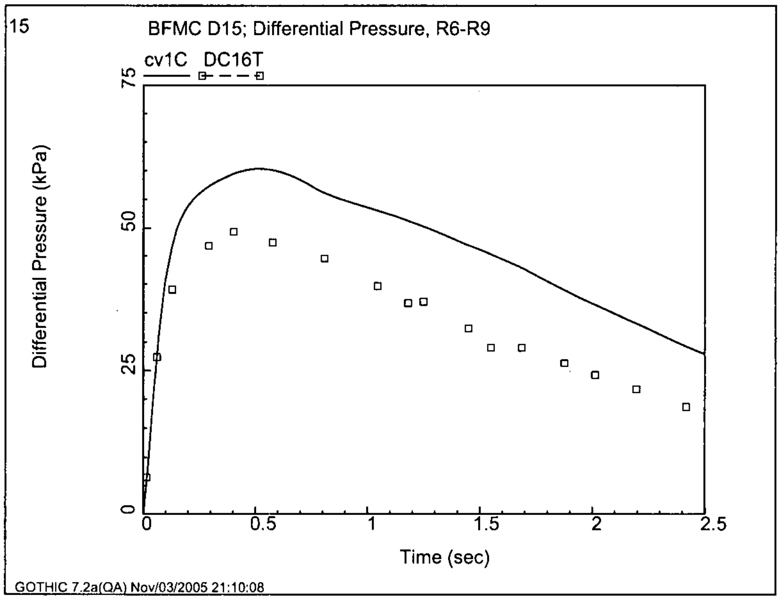

Figure 4-13 BFMC D-15, C2C Differential Pressure between Rooms R6 and R9

a,c

Figure 4-14 BFMC D-15, Equ 2-2 Differential Pressure between Rooms R6 and R9

Battelle-Frankfurt Test D-16 Result Comparison

Battelle-Frankfurt test D-16, which is modeled as shown in Figure 4-15, is a pressurized water blowdown experiment. This test is, in some notable respects, uniquely different from tests D-1 and D-15. The break room configuration in test D-16 provides non-symmetric parallel flow paths from the break room to the dome. A second unique aspect of the current test is the fluid condition of the break. The blowdown is pressurized liquid, whereas tests D-1 and D-15 are steam blowdowns.

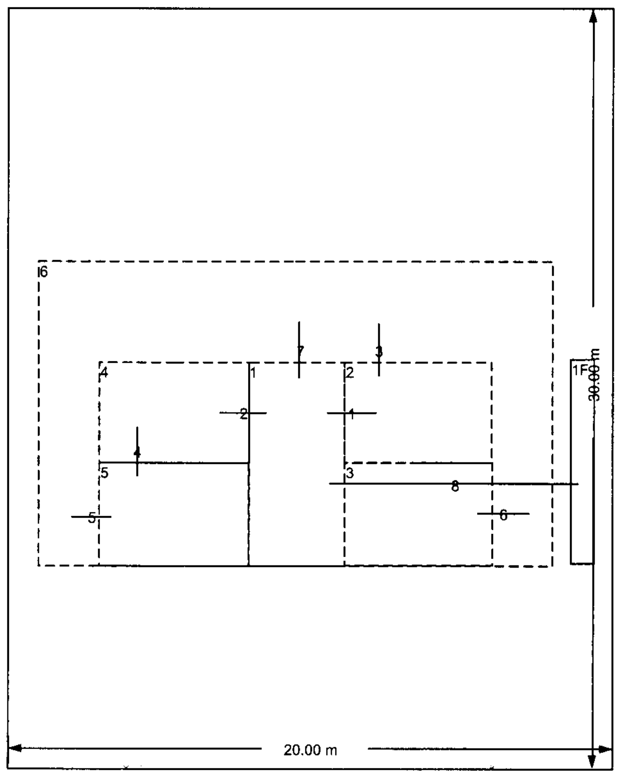

Figure 4-15 GOTHIC Model of BFMC Test D-16

In this test, the break location is in room 1 (lumped volume #1). The break flow is represented by flow boundary condition 1F. Inertia lengths of flow paths 1 through 7 have been re-calculated using GOTHIC recommended formula of Equation 2-2.
Table 4-3 summarizes the C2C and Equ 2-2 values of inertia length for affected flow paths.

Table 4-3 C2C and Equ 2-2 Inertia Lengths for BFMC Test D-16

Flow Path	C2C	Equ 2-2
Flow Path #1	5.34	[ ] a,c
Flow Path #2	5.34	[ ] a,c
Flow Path #3	3	[ ] a,c
Flow Path #4	10	[ ] a,c
Flow Path #5	3	[ ] a,c
Flow Path #6	3	[ ] a,c

Flow Path #7	3	[ ] a,c

Figures 4-16 and 4-17 show the C2C and Equ 2-2 differential pressure between room R4 and room R5

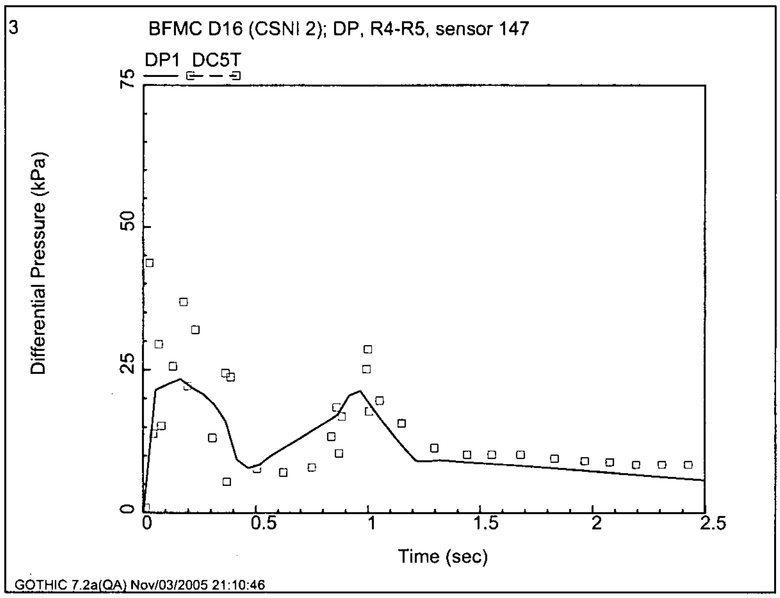

Figure 4-16 BFMC D-16, C2C Differential Pressure between Rooms R4 and R5

a,c

[ ]

Figure 4-17 BFMC D-16, Equ 2-2 Differential Pressure between Rooms R4 and R5

[ ] a,c

Figures 4-18 and 4-19 show the differential pressure between room R4 and R7.
[

] a,c

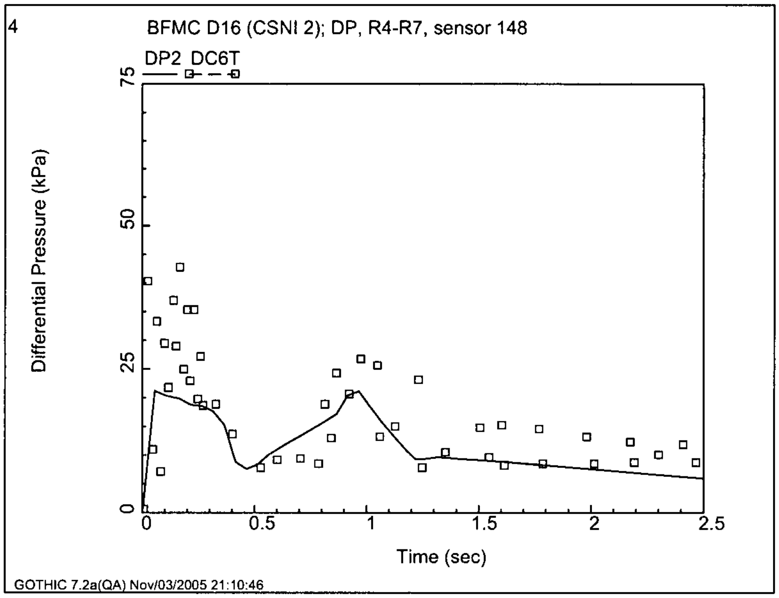

Figure 4-18 BFMC D-16, C2C Differential Pressure between Rooms R4 and R7

a,c

Figure 4-19 BFMC D-16, Equ 2-2 Differential Pressure between Rooms R4 and R7

Figures 4-20 and 4-21 show the C2C and Equ 2-2 differential pressure between rooms R4 and R9.

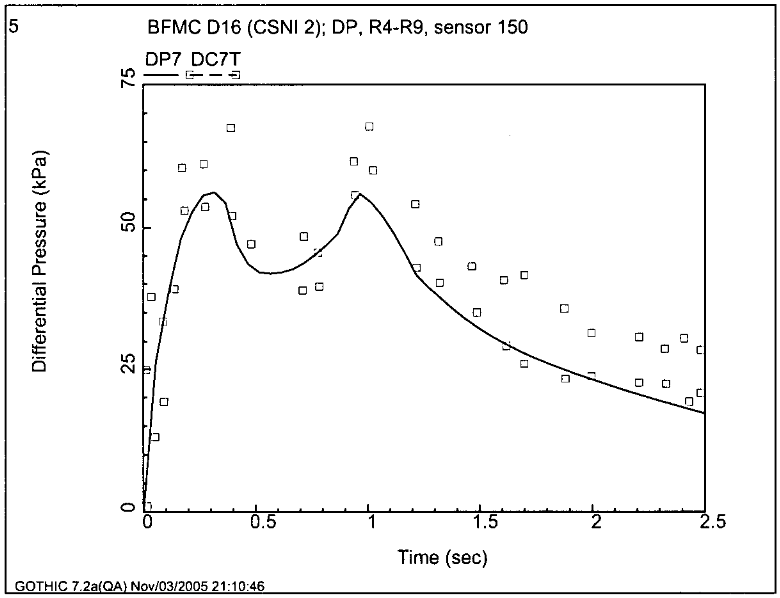

Figure 4-20 C2C Differential Pressure between Rooms R4 and R9

[ ]a,c

Figure 4-21 Equ 2-2 Differential Pressure between Rooms R4 and R9

[ ]a,c

HDR Test V21.1 Result Comparison

The Heissdampfreaktor (HDR) is a decommissioned superheated steam reactor in the Federal Republic of Germany. Following its decommissioning, the HDR reactor vessel and containment system were used in an experimental role designated as Project HDR.

GOTHIC was used to simulate a number of HDR blowdown tests. In the current investigation, HDR test V21.1 was used. Test V21.1 was a water blowdown in which the break flow was extracted from the liquid region near the bottom of the pressure vessel. The parameter of interest was the vent openings between the break room and the adjacent rooms.

Figure 4-22 shows the GOTHIC model for the HDR facility.

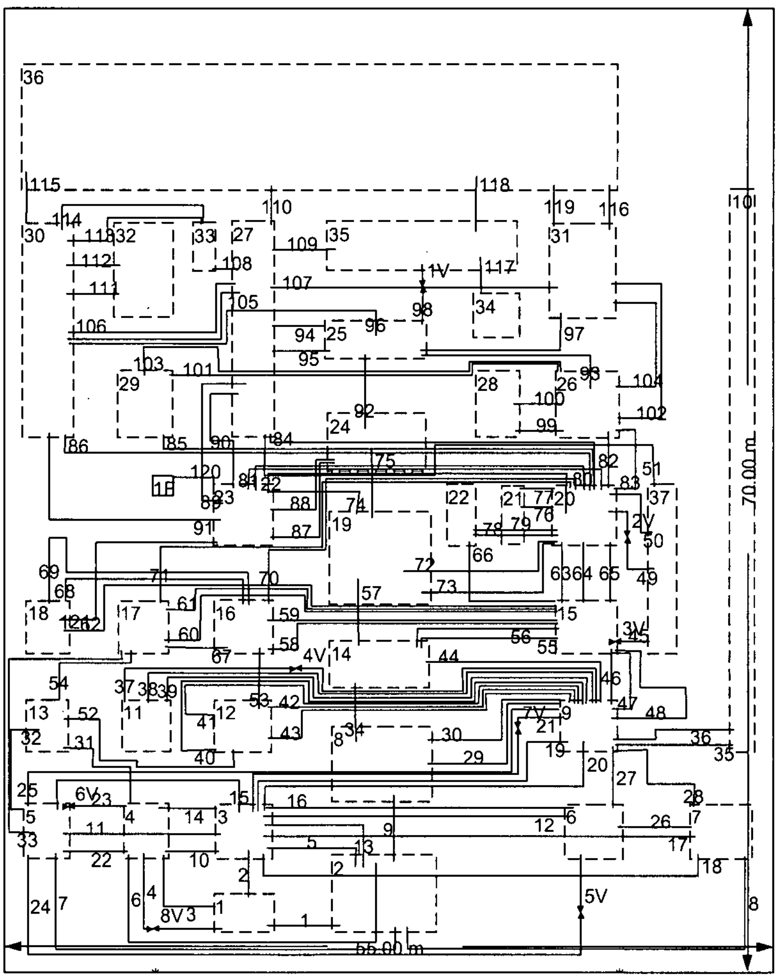

Figure 4-22 GOTHIC Model for HDR Test V21.1

Since the primary interest of this test was to investigate the vent opening between the break room (lumped volume #23) and the adjacent rooms, only the inertia lengths for the flow paths

connecting the break room to adjacent rooms were re-calculated using the GOTHIC recommended formula. Table 4-4 shows a list of C2C and Equ 2-2 values for inertia length for the flow paths modeled.

Table 4-4 C2C and Equ 2-2 Inertia Lengths for HDR Test V21.1

Flow Path	C2C	Equ 2-2
Flow Path #74	5	[ ] a,c
Flow Path #80	10	[ ] a,c
Flow Path #81	10	[ ] a,c
Flow Path #87	4	[ ] a,c
Flow Path #88	4	[ ] a,c
Flow Path #89	7	[ ] a,c
Flow Path #90	7	[ ] a,c
Flow Path #91	4	[ ] a,c
Flow Path #121	5	[ ] a,c
Flow Path #122	8	[ ] a,c

Of particular interest are rooms 19, 24, 27, and 30. The following graphs show the C2C and Equ 2-2 differential pressure between the break room 23 (break room) and the rooms of interest.

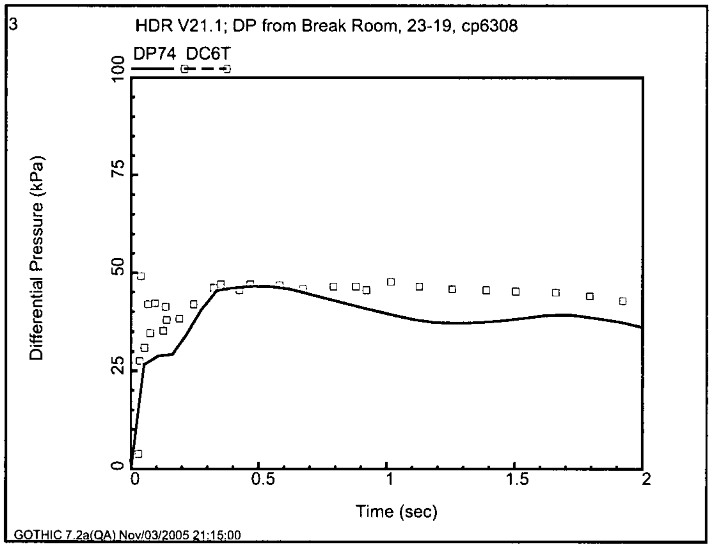

Figure 4-23 HDR V21.1, C2C Differential Pressure between Rooms R23 and R19

[ ]a,c

Figure 4-24 HDR V21.1, Equ 2-2 Differential Pressure between Rooms R23 and R19

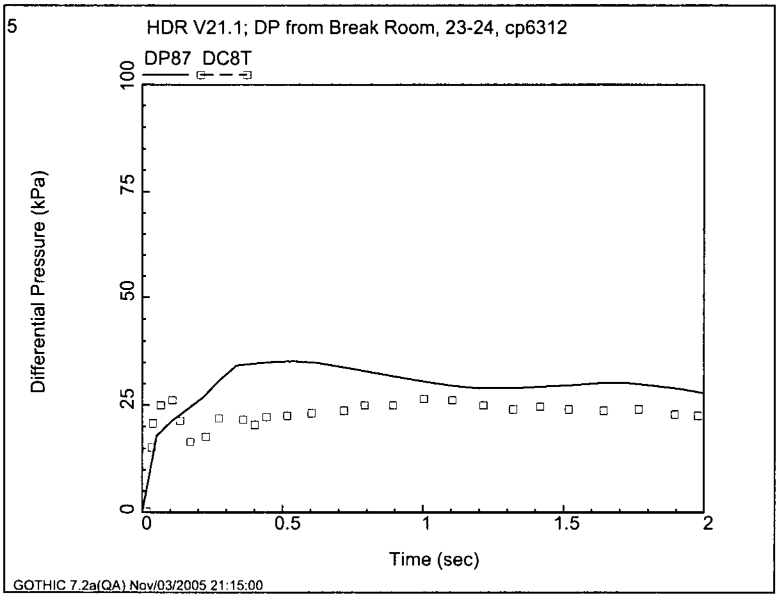

Figure 4-25 HDR V21.1, C2C Differential Pressure between Rooms R23 and R24

a,c

[ ]

Figure 4-26 HDR V21.1, Equ 2-2 Differential Pressure between Rooms R23 and R24

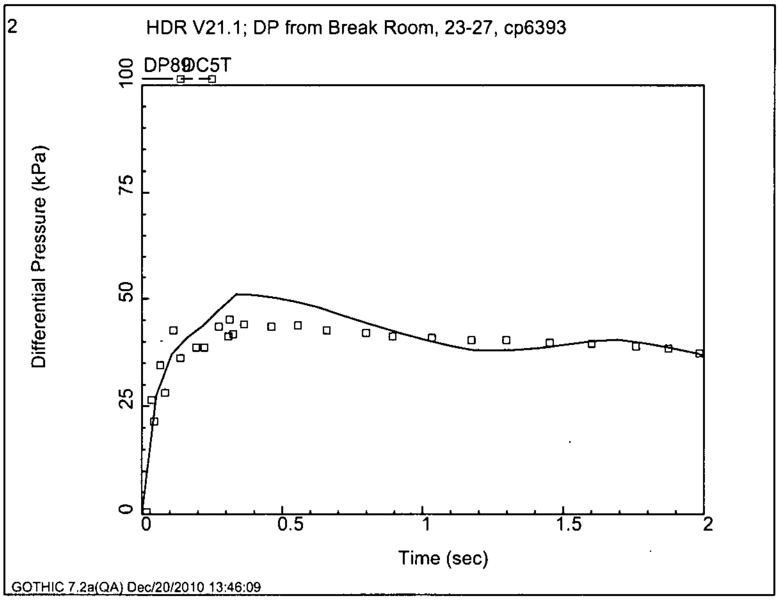

Figure 4-27 HDR V21.1, C2C Differential Pressure between Rooms R23 and R27

a,c

Figure 4-28 HDR V21.1, Equ 2-2 Differential Pressure between Room R23 and R27

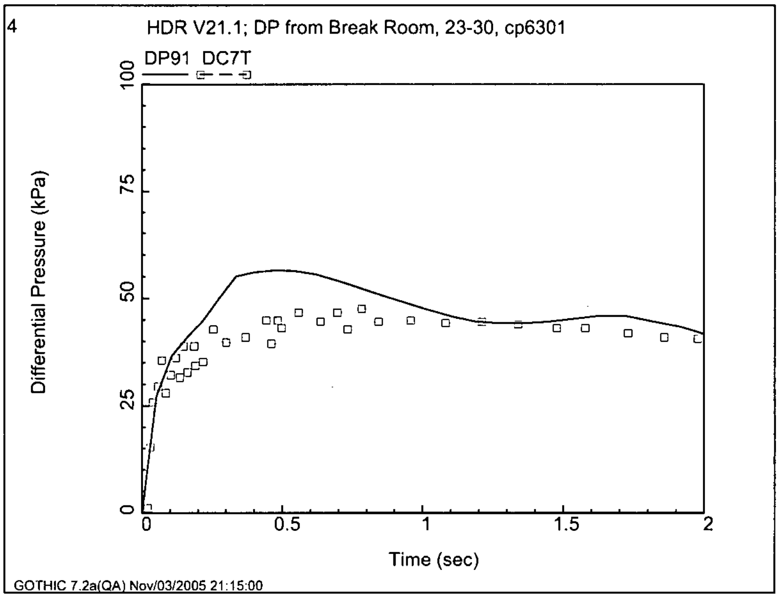

Figure 4-29 HDR V21.1, C2C Differential Pressure between Rooms R23 and R30

[ ] a,c

Figure 4-30 HDR V21.1, Equ 2-2 Differential Pressure between Rooms R23 and R30

Summary of Maximum Differential Pressure Ratio Results for Selected Tests

Test (Break Flow)	Measurement Location	$L_{Equ\ 2\text{-}2}/L_{C2C}$[1]	$\Delta P_{Equ\ 2\text{-}2}/\Delta P_{C2C}$[1]	Time of Differential Pressure Peak (s)	
				C2C[1]	Equ 2-2[1]
BFMC Test D-1 (Steam)	R6-R4	[ ] a,c	[ ] a,c	0.298	[ ] a,c
	R4-R9	[ ] a,c	[ ] a,c	0.298	[ ] a,c
	R6-R9	Not connected	[ ] a,c	0.298	[ ] a,c
BFMC Test D-15 (Steam)	R5-R9	[ ] a,c	[ ] a,c	0.837	[ ] a,c
	R8-R7	[ ] a,c	[ ] a,c	0.297	[ ] a,c
	R6-R9	Not connected	[ ] a,c	0.517	[ ] a,c
BFMC Test D-16 (Two phase)	R4-R5 (1st peak)	[ ] a,c	[ ] a,c	0.167	[ ] a,c
	R4-R5 (2nd peak)	[ ] a,c	[ ] a,c	0.967	[ ] a,c
	R4-R7 (1st peak)	[ ] a,c	[ ] a,c	0.055	[ ] a,c
	R4-R7 (2nd peak)	[ ] a,c	[ ] a,c	0.967	[ ] a,c
	R4-R9 (1st peak)	[ ] a,c	[ ] a,c	0.317	[ ] a,c
	R4-R9 (2nd peak)	[ ] a,c	[ ] a,c	0.967	[ ] a,c
HDR Test V21.1 (Two phase)	R23-R19	[ ] a,c	[ ] a,c	0.478	[ ] a,c
	R23-R24	[ ] a,c	[ ] a,c	0.542	[ ] a,c
	R23-R27	[ ] a,c	[ ] a,c	0.336	[ ] a,c
	R23-R30	[ ] a,c	[ ] a,c	0.478	[ ] a,c

Footnote 1: "Equ 2-2" represents inertia length according to Equation 2-2 of WCAP-17065-P.
"C2C" represents inertia length based on room center-to-center distance.

References

1. NAI 8907-09 Revision 9, GOTHIC Containment Analysis Package Qualification Report, Version 7.2a(QA), January 2006.

Attachment 3

Request for Withholding Proprietary Information

Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC

U7-C-NINA-NRC-120054

CAW-12-3511

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared B. F. Maurer, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse), and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

B. F. Maurer, Manager
ABWR Licensing

Sworn to and subscribed before me
this 17th day of July 2012

Notary Public

COMMONWEALTH OF PENNSYLVANIA
NOTARIAL SEAL
Renee Giampole, Notary Public
Penn Township, Westmoreland County
My Commission Expires September 25, 2013

(1) I am Manager, ABWR Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse), and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rule making proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse Application for Withholding Proprietary Information from Public Disclosure accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's

competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390; it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked in WCAP-17065-P-A, Revision 0, "Westinghouse ABWR Subcompartment Analysis Methodology Using GOTHIC" (Proprietary) for submittal to the Commission, being transmitted by Nuclear Innovation North America (NINA) letter and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with the review of the subcompartment analysis methodology in support of Westinghouse ABWR fuel products.

This information is part of that which will enable Westinghouse to:

(a) Assist the customer in obtaining NRC review of the Westinghouse subcompartment analysis methodology as applied to ABWR plant designs.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of this information to its customers for purposes of plant specific ABWR subcompartment analysis for licensing basis applications.

(b) Its use by a competitor would improve their competitive position in the design and licensing of a similar product for ABWR subcompartment analysis methodology.

(c) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluations and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

Proprietary Information Notice

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

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