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Our ref: CAW-09-2606

June 25, 2009

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: WCAP-17058-P, "Implementation of ABWR DCD Methodology using GOTHIC for STP 3 and 4 Containment Design Analyses" (Proprietary)

The proprietary information for which withholding is being requested in the above-referenced report is further identified in Affidavit CAW-09-2606 signed by the owner of the proprietary information, Westinghouse Electric Company LLC. The affidavit, which accompanies this letter, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in paragraph (b)(4) of 10 CFR Section 2.390 of the Commission's regulations.

Accordingly, this letter authorizes the utilization of the accompanying affidavit by South Texas Project Nuclear Operating Company.

Correspondence with respect to the proprietary aspects of the application for withholding or the Westinghouse affidavit should reference this letter, CAW-09-2606, and should be addressed to B. F. Maurer, Manager, ABWR Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

B. F. Maurer, Manager
ABWR Licensing

G. Bacuta (NRC OWFN 12E-1)

Enclosures

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

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 25th day of June, 2009

Sharon L. Markle
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Sharon L. Markle, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Jan. 29, 2011
Member, Pennsylvania Association of Notaries

(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" 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-17058-P, "Implementation of ABWR DCD Methodology using GOTHIC for STP 3 and 4 Containment Design Analyses" (Proprietary) for submittal to the Commission, being transmitted by South Texas Project Nuclear Operating Company (STPNOC) 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 South Texas Project Units 3 and 4 COL Application.

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

(a) Assist the customer in obtaining NRC review of the South Texas Project Units 3 and 4 COL Application.

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 containment 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 containment analyses.

(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 calculations 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).

Copyright Notice

WCAP-17058-NP
Revision 0

June 2009

Implementation of ABWR DCD Methodology using GOTHIC for STP 3 and 4 Containment Design Analyses

Westinghouse

WCAP-17058-NP
Revision 0

Implementation of ABWR DCD Methodology using GOTHIC for STP 3 and 4 Containment Design Analyses

Richard P. Ofstun*
Engineering Services, Safety Analysis and Licensing

Thomas L. George
Numerical Applications, Inc.

June 2009

Reviewer: Jason Douglass*
Engineering Services, Safety Analysis and Licensing

Approved: Kent Bonadio*, Manager
Engineering Services, Safety Analysis and Licensing

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

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1 INTRODUCTION AND BACKGROUND

The General Electric Company (GE) submitted an application for final design approval (FDA) and standard design certification for the U.S. version of the advanced boiling water reactor (ABWR) to the United States Nuclear Regulatory Commission (NRC) in March 1989. The NRC issued their Final Safety Evaluation Report (FSER) for the ABWR design in July 1994 (Reference 1). GE produced revisions to the ABWR design control document (DCD); the most recent, Revision 4, was submitted in March 1997 (Reference 7). The NRC granted final design certification for the ABWR in June 1997.

NRG Energy/South Texas Project Nuclear Operating Company (STPNOC) submitted a combined construction and operating license application (COLA) for two ABWR units at their South Texas site. Toshiba, GE, and Hitachi had worked together to license and construct several ABWR plants in Japan. Based on this experience, NRG Energy/STPNOC engaged Toshiba to work with GE to license and construct the two units.

The containment analyses that were performed for other ABWR plants identified several improvements and corrections that should be made in the U.S. ABWR DCD modeling assumptions. In September 2007, GE submitted licensing topical report (LTR) NEDO-33372 for NRC review (Reference 2). This LTR was written to document improvements and corrections to the ABWR containment modeling assumptions and the new analysis results for the U.S. ABWR DCD at the request of South Texas Project (STP) Units 3 and 4.

In October 2007, GE notified the NRC that they were temporarily suspending technical support for the review of NEDO-33372 and twelve other topical reports supporting an anticipated ABWR DCD amendment. Toshiba offered to complete both the licensing and construction efforts and subsequently contracted with Westinghouse to assist them with the licensing and analysis support effort for the South Texas ABWR plants.

2 PURPOSE

The containment analysis methodology that was used for the ABWR DCD analyses is based on GE LTR NEDO-20533 (Reference 3). The NEDO-20533 methodology was originally approved to analyze the containment response for the Mark III containment design; therefore, some changes were needed to perform the ABWR containment design analyses for the DCD. GE provided justification to the NRC that the NEDO-20533 methodology, as modified in the ABWR DCD, is applicable for analyzing the containment response for the ABWR containment design.

Westinghouse does not have access to the GE code (M3CPT) described in NEDO-20533. Instead, Westinghouse uses the GOTHIC code (Reference 4) for containment design analyses.

Therefore, the purpose of this report is to document and demonstrate the Westinghouse implementation of the NEDO-20533 methodology, as modified in the ABWR DCD, using the GOTHIC code. This document provides:

1. A description of the Westinghouse GOTHIC ABWR containment model.

2. A comparison of the NEDO-20533, DCD, and GOTHIC ABWR containment modeling methodologies.

3. A comparison of the transient results from the GOTHIC ABWR containment model with the DCD transient results for the short-term feedwater line break (FWLB) and main steam line break (MSLB) peak pressure cases.

Finally, the corrections that were identified by GE in NEDO-33372 were incorporated into the GOTHIC ABWR containment model and short- and long-term FWLB and MSLB cases were run. The results for these cases are also included in this report. The results presented in this topical report will become the licensing basis for the STP COLA.

3 GOTHIC ABWR CONTAINMENT MODEL DESCRIPTION

The ABWR uses a pressure suppression type containment design (Figure 3-1). The primary containment consists of a drywell and a wetwell. The drywell is separated into an upper and lower volume by the reactor pedestal. The upper drywell houses the reactor vessel and associated steam and feedwater piping. The lower drywell houses the internal pump motors and control rod drives. The reactor pedestal contains ten vertical ducts that connect the upper and lower drywells with the vertical vent pipes that run down to the suppression pool. Three parallel, horizontal vent tubes extend from each vertical vent pipe; the top vent tube is located about 3.5 m below the surface of the suppression pool. A diaphragm floor, which is firmly attached to the reactor pedestal, separates the drywell and wetwell volumes. The wetwell contains the suppression pool and a nitrogen filled space above the pool.

For the Mark III containment design, peak containment pressures are reached within a few seconds of the break, during the vent clearing phase. The ABWR containment peak pressures are higher than those in the Mark III containment and occur towards the end of blowdown, when most of the initial gas in the drywell has been transferred to the wetwell gas space. Even though the ABWR drywell to wetwell vent flow path is more restrictive, the wetwell gas space in the ABWR is much smaller than in the Mark III design leading to the higher peak pressure later in the transient. Consequently, the details of the vent clearing modeling are less important in the ABWR than in the Mark III design because in the ABWR the peak pressure does not occur during the vent clearing phase.

The GOTHIC ABWR primary containment model noding structure is shown in Figure 3-2. The noding structure is based on the descriptions provided in NEDO-20533 and the ABWR DCD.

The upper and lower drywell regions of the ABWR containment are modeled as a single lumped parameter control volume, consistent with the ABWR DCD. As a result, perfect mixing between the upper and lower drywell regions is assumed during the event.

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The wetwell region is modeled as a single lumped parameter control volume. Vacuum breakers are located between the wetwell and drywell gas spaces to allow air from the wetwell to travel back to the drywell after the drywell begins to depressurize. The flow path that connects the wetwell gas space to the drywell gas space uses a valve component to model the vacuum breakers.

There are three trains in the ABWR emergency core cooling system (ECCS). Each train has a high pressure pump, a low pressure pump, and a residual heat removal (RHR) heat exchanger. The low pressure pumps take suction from the suppression pool. The high pressure pumps normally take suction from the condensate storage tank (CST) and are automatically realigned to take suction from the suppression pool if the CST water level is too low or the suppression pool water level is too high. Since the CST is not safety grade, the high pressure pumps are assumed to draw suction from the suppression pool in the design analyses. The high pressure core flooder (HPCF) and low pressure flooder (LPFL) pumps in Trains B and C deliver ECCS flow to the vessel through dedicated lines. The high pressure pump in Train A is a reactor core isolation cooling (RCIC) pump and is driven by a steam turbine. Both the RCIC pump and LPFL pump in Train A deliver injection flow through the feedwater line. The LPFL pumps in Trains A and B can be realigned for either spray or pool cooling, but the LPFL pump in Train C can only be realigned for pool cooling.

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The short-term mass and energy releases are calculated separately from the GOTHIC containment model. The short-term mass and energy releases for the DCD benchmark comparison cases were recalculated to replicate the DCD analysis input values.

The short-term mass and energy releases for the updated analysis cases were calculated using the Westinghouse boiling water reactor (BWR) loss of coolant accident (LOCA) mass and energy release input calculation methodology documented in Reference 5. This reference describes how the Westinghouse BWR ECCS analysis model, which is based on the GOBLIN code, is modified to conservatively calculate the mass and energy releases for the containment analysis. A similar approach was used to modify the ABWR GOBLIN ECCS evaluation model so it could calculate the short-term mass and energy releases for the containment analysis.

The short-term mass and energy releases are input to the containment model using control variables and flow boundary conditions. The boundary conditions representing the break releases are connected to the drywell control volume. Flow boundary conditions are also connected to the suppression pool to remove the ECCS injection flow calculated by the short-term mass and energy release model.

The Automatic Depressurization System (ADS) consists of eight safety/relief valves that can be used to depressurize the reactor vessel. The ADS flow rate and enthalpy is calculated by the GOBLIN short-term mass and energy release model and input to GOTHIC using a specified flow boundary condition. The boundary condition representing the safety relief valve (SRV) releases is connected to the wetwell control volume.

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The key input data for the GOTHIC ABWR containment model are presented in Appendix A.

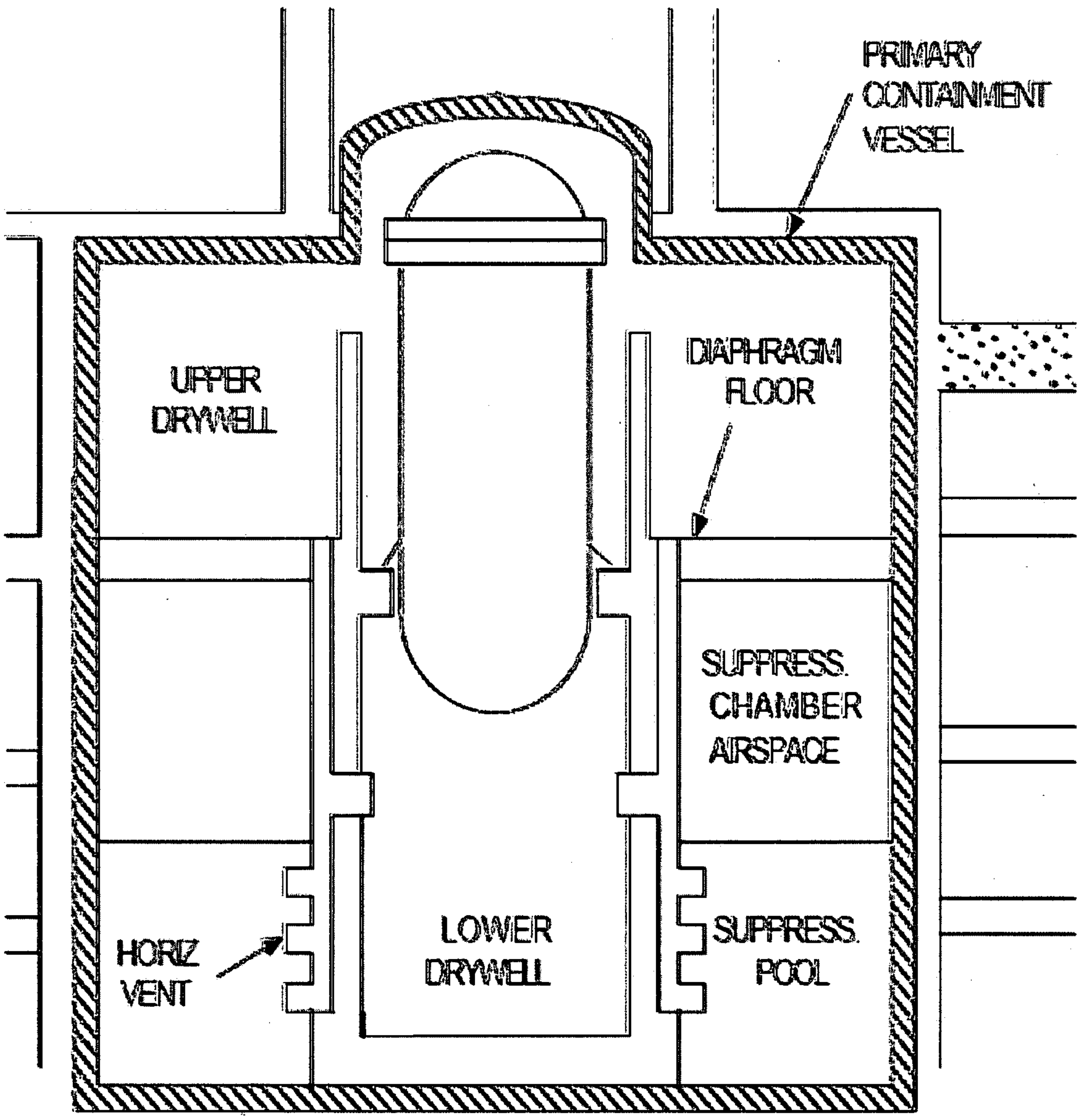

Figure 3-1 ABWR Primary Containment

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Figure 3-2 GOTHIC ABWR Containment Model Noding Diagram

4 COMPARISON OF THE NEDO-20533, DCD, AND GOTHIC ABWR CONTAINMENT MODELING METHODOLOGY

4.1 DRYWELL MODELING METHODOLOGY

The differences between the NEDO-20533, DCD, and GOTHIC ABWR drywell modeling methodology for peak pressure analyses are summarized in Table 4-1.

NEDO-20533 uses a single volume to model the drywell for the Mark III containment design. The ABWR containment design consists of an upper and lower drywell. The upper and lower drywell volumes were combined for the ABWR DCD analyses. However, different drywell volume input values were used for the FWLB and MSLB events. The whole lower drywell volume is assumed to be perfectly mixed with the upper drywell volume during a MSLB event, but only half of the lower drywell volume is assumed to mix with the upper drywell for the FWLB event. The GOTHIC ABWR containment model uses this same approach to be consistent with the ABWR containment design analysis methodology documented in the DCD.

The drywell vapor region calculational approach outlined in NEDO-20533 solves two mass equations (one for steam/water and the other for gas) and one energy equation for the steam/water/gas mixture. For some specific portions of the transient (e.g., vent flow phase), NEDO-20533 treats steam as an ideal gas, while GOTHIC always uses steam tables to obtain the steam properties. NEDO-20533 does not model a drop field, but GOTHIC does. GOTHIC solves three mass equations (one for steam, one for gas, and one for drops) and two energy equations (one for steam/gas and one for 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 similar to what is assumed in NEDO-20533. [

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For the liquid/steam flow split of the break flow, NEDO-20533 assumes that the entering steam/water mixture comes into thermal equilibrium with the containment atmosphere, maximizing the steam generation rate. The GOTHIC ABWR containment model uses a break flow split modeling approach that is similar. The break liquid is assumed to be released to the atmosphere as small drops [

]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 equilibrium with the containment atmosphere, consistent with the NEDO-20533 assumption. Before the containment peak pressure is reached, the NEDO-20533 methodology transfers water coming from the MSLB directly to the suppression system vent. This special treatment of the break flow was not done for the ABWR DCD analysis and has not been included in the GOTHIC methodology.

4.2 VENT MODELING METHODOLOGY

The differences between the NEDO-20533, DCD, and GOTHIC ABWR vent modeling methodology for peak pressure analyses are summarized in Table 4-2.

NEDO-20533 describes the modeling of the vent clearing process in detail. In the Mark III containment design, the modeling of the vent clearing process is very important because the drywell peak pressure occurs during the vent clearing phase of an MSLB event. Since the ABWR containment design has a much smaller wetwell airspace volume, the peak pressure is expected to occur near the end of blowdown, when most of the nitrogen gas has been purged from the drywell. While the vent clearing process is important, the key factors that determine the peak pressure for the ABWR are: the ratio of wetwell to drywell gas volume, vent submergence (initial water level in the wetwell), and the vent path resistance (form and friction losses).

In the NEDO-20533 calculational approach, both the vertical vent pipe and horizontal vent tubes are modeled with control volumes. Vapor from the vertical vent pipe starts to flow to the horizontal vent tube only after the fluid level in the vertical vent pipe control volume falls below the centerline of the vent tube control volume. The water in the horizontal vent tube control volume is pushed into the wetwell volume like a slug as the vent tube starts to fill with vapor. This method produces a rapid change in the flow quality to the suppression pool, which occurs after the all the water is pushed out of the horizontal vent tube. The ABWR DCD does not specify the vertical vent liquid level at which the steam/gas flow starts to clear the horizontal vent

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The gravity head of water is included in the NEDO-20533 calculational approach, but the gravity head of the vapor phase (steam/gas) is ignored. The GOTHIC code automatically calculates and accounts for the gravity head of both liquid and vapor.

The NEDO-20533 calculational approach accounts for the effect of liquid inertia in the vents prior to vent clearing, but ignores inertia after vent clearing. The GOTHIC code calculates and accounts for the liquid, vapor, and drop inertia in the momentum equation solution at all times.

The effective inertia length that is recommended to be used in the NEDO-20533 calculational approach includes 125% of the horizontal vent tube diameter. The recommended effective inertia length input for a GOTHIC model is similar; it includes 130% of the horizontal vent tube diameter. The effective inertia length input values that were used in the ABWR DCD analysis are unknown; however, based on GOTHIC sensitivity studies, it is apparent that the assumed inertia length was very short. [

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The NEDO-20533 calculational approach assumes no slip between the liquid and vapor phases flowing through the vent system. This assumption increases the calculated pressure drop through the vent system. [

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The NEDO-20533 approach assumes that an ideal gas mixture containing steam and nitrogen gas is flowing through the horizontal vents when calculating the choked flow rate. The homogeneous equilibrium (HEM) choking model is used in GOTHIC. It considers a mixture of steam, water, and nitrogen gas at equal temperature and velocity to calculate the choked flow rate through the horizontal vents.

The horizontal vent downstream pressure modeling is different between the NEDO-20533 calculational approach and GOTHIC. When the gas from the drywell enters the suppression pool, the pressure in the bubbles must be large enough to expand the bubbles against the gravitational head of water in the pool and the inertia of the water above the bubbles. A separate bubble back pressure model is included in the NEDO-20533 approach to account for this effect. Once the vents have cleared, and the initial pool bubbles break through the pool surface, the inertial effects on the bubble pressure become small. In the GOTHIC code, the gravitational head of the pool is fully accounted for, but the inertia effect of the bubble expansion is ignored. This is justified because the drywell pressurization during the vent clearing and initial pool swell, when the bubble inertia effect is important, is not controlling for the ABWR peak pressure.

NEDO-20533 is not specific regarding the form loss factors. Examination of the momentum balances for the vertical and horizontal vent flows reveals that there are some built in losses due to the specific treatment of the momentum transport terms. It is not clear if additional loss factors are included. The DCD specifies that a variable loss factor between 2.5 and 3.5 is used depending on the number of open horizontal vents. Apparently, these are in addition to the built in losses from the treatment of the momentum transport. In benchmarking the GOTHIC ABWR containment model against the DCD results for the FWLB, a variable loss factor similar to that assumed in the DCD model was used. The GOTHIC code also includes some built in losses due to the treatment of the momentum transport terms, similar to those described in NEDO-20533. Since the vent losses are a major controlling factor for the peak pressure in the MSLB and FWLB cases, the benchmark comparison demonstrates that the modeling of the vent losses in the GOTHIC ABWR containment model is consistent with the previously accepted methods.

4.3 WETWELL MODELING METHODOLOGY

The differences between the NEDO-20533, DCD, and GOTHIC ABWR wetwell modeling methodology for peak pressure analyses are summarized in Table 4-3.

The initial suppression pool water volume is maximized in the NEDO-20533 modeling approach. This minimizes the wetwell gas volume and maximizes the hydrostatic head in the wetwell to maximize the calculated peak drywell pressure. In the DCD analyses, the suppression pool water volume input value is based on the low water level (LWL) value and the gas space volume input value is based on the high water level (HWL) value. This same approach is used in the GOTHIC ABWR containment benchmark model for the DCD benchmark comparison, but this inconsistency is removed in the GOTHIC ABWR containment analysis model.

In the NEDO-20533 modeling approach, all of the steam from the steam/gas mixture that passes through the vents is assumed to condense in the suppression pool. The remaining gas is assumed to enter the wetwell gas space at the pool temperature with 100% relative humidity.

In GOTHIC, the steam condensation rate from the steam/gas mixture passing through the submerged vents is calculated using interfacial heat and mass transfer models between the water and the steam/gas bubbles. GOTHIC predicts that essentially all of the steam is condensed in the suppression pool for the ABWR FWLB and MSLB events.

In the NEDO-20533 modeling approach, the gas/steam mixture in the wetwell gas space is assumed to be at the same temperature as the suppression pool. Since the ABWR wetwell gas space is much smaller than the Mark III containment design, the wetwell gas space pressure and temperature will increase faster as the drywell gas is transferred to the wetwell. This contributes to the pressurization of the wetwell and drywell; therefore, the thermal equilibrium assumption may not be justified. The ABWR DCD is not specific regarding the heat and mass transfer at the pool surface, but it does indicate that the temperature of the gas space was allowed to increase beyond the pool temperature. This indicates the pool and wetwell gas/steam mixture are not maintained in thermal equilibrium as specified in NEDO-02533.

GOTHIC uses interfacial heat and mass transfer models to calculate the mass and energy transfer at the pool surface. The pool surface liquid-vapor interface area is a user input. [

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4.4 INITIAL CONDITIONS

Consistent with the ABWR DCD and accepted methods for calculating the containment peak pressure and temperature, the initial drywell and wetwell temperatures are set to the specified maximum values and the initial humidity is set to the minimum specified value.

The suppression pool water level is biased high for the peak pressure calculation. This minimizes the wetwell gas space volume and maximizes the vent submergence which results in a higher calculated drywell peak pressure.

For the DCD peak pressure analysis, the suppression pool water volume input value is based on the low water level (LWL) value and the gas space volume input value is based on the high water level (HWL) value. This same approach is used in the GOTHIC ABWR containment benchmark model for the DCD benchmark comparison.

Table 4-1 Differences in Drywell Modeling Methodology for Peak Pressure Analyses

	NEDO-20533	ABWR DCD	GOTHIC ABWR
Noding Structure	Single volume.	FWLB – Single volume, upper drywell combined with 50% of lower drywell volume. MSLB – Single volume, upper drywell and full lower drywell volumes combined.	FWLB – Single volume, upper drywell combined with 50% of lower drywell volume. MSLB – Single volume, upper drywell and full lower drywell volumes combined.
Break Flow	Homogeneous mixture of steam/water is added to the vapor space. For MSLB, water release before peak pressure goes directly to the suppression system vent.	Homogeneous mixture of steam/water is added to the vapor space.	Simulates the addition of a homogeneous mixture of steam/water to the vapor space. [ ]a,c
Mass Balance	Two separate mass balances; one for steam/water and one for gas.	Same as NEDO-20533.	Three separate mass balances; one for steam, one for gas, and one for drops.
Energy Balance	Single homogeneous mixture of steam/water and gas at saturated or superheated conditions.	Same as NEDO-20533.	Two separate energy balances; one for the steam/gas mixture and one for drops. Code calculates interface heat and mass transfer between vapor and drops.

Table 4-2 Differences in Vent System Modeling Methodology for Peak Pressure Analyses			
	NEDO-20533	**ABWR DCD**	**GOTHIC ABWR**
Noding Structure	Coincident mass and momentum control volumes.	Same as NEDO-20533.	Staggered grid for mass and momentum control volumes.
Gravity Head	Included for water, ignored for the steam/gas mixture.	Same as NEDO-20533.	Included for all phases.
Inertia	Included for water during vent clearing, ignored after vent clearing.	Same as NEDO-20533.	Included for all phases at all times.
Effective Inertia Length	$L_{vent} + 1.25\ D_{vent}$	Unknown, but appears to have been a small value.	Small value.
Interfacial Slip	No interfacial slip.	Same as NEDO-20533.	Small due to small drop diameter.
Choked flow	Calculated for an ideal gas mixture of gas/steam at the horizontal vent tubes.	Same as NEDO-20533.	Calculated for a mixture of gas/steam/water at the horizontal vent tubes using the Homogeneous Equilibrium Model.
Upstream Pressure	Stagnation pressure in vertical vent pipe at horizontal vent tube centerline.	Same as NEDO-20533.	Static pressure in vertical vent pipe at the horizontal vent tube bottom.
Downstream Pressure	Gas space pressure + hydrostatic head + bubble inertia pressure.	Same as NEDO-20533.	Gas space pressure + hydrostatic head.
Friction Losses	Included in the horizontal vent tubes after clearing.	Unknown.	Included in the specified form loss factors.
Form Losses	Document is not specific; equations appear to have built-in values of 2 for water flowing in the vertical vent pipe and 1 for the gas/water in horizontal vent tube.	Variable value between 2.5 and 3.5, depending on the number of vents open. Document is not specific on location.	Variable loss factor [ ]^{a,c}.

U7-C-STP-NRC-090067
Attachment 3

Table 4-3 Differences in Wetwell Modeling Methodology for Peak Pressure Analyses

	NEDO-20533	ABWR DCD	GOTHIC ABWR
Water Volume	Maximized.	Minimized.	Maximized.
Gas Volume	Minimized.	Minimized.	Minimized.
Mass Balance	Incoming steam and water is added to the pool water mass. Incoming air is transferred to the gas space. Water vapor is added to the gas space to maintain 100% relative humidity.	Same as NEDO-20533.	Mass balances are maintained for the steam, water, and gas in the wetwell.
Energy Balance	Energy is balanced in the pool, but not the gas space. Air is added to the gas space at the pool temperature.	Energy is balanced in both the pool and gas space.	Energy balances are maintained for the steam, water, and gas in the wetwell.
Interface Heat and Mass Transfer	Thermal equilibrium is maintained between the pool and gas space.	Unknown, but appears to be minimal between the pool and gas space.	Interface heat and mass transfer is modeled between the air/steam bubbles and the pool as well as between the pool and the gas space.

5 GOTHIC ABWR CONTAINMENT BENCHMARK MODEL RESULTS

The GOTHIC ABWR containment benchmark model results for the short-term FWLB and MSLB events are compared with the results from the DCD. The key input data for the GOTHIC ABWR containment benchmark model are presented in Table A-1 of Appendix A.

5.1 FEEDWATER LINE BREAK COMPARISON

The FWLB mass and energy release input data for the benchmark comparison is presented in Figures B-1 through B-4 of Appendix B.

Figures 6.2-6 and 6.2-7 of the DCD were digitized to produce the benchmark pressure and temperature data for comparison with the GOTHIC ABWR containment benchmark model. Please note, the peak drywell pressure value that is shown in DCD Figure 6.2-6 (about 356 kPaA = 51.6 psia) is lower than the DCD Table 6.2-1 value of 268.7 kPaG = 53.68 psia. The value that is stated in DCD Table 6.2-1 was assumed to be correct.

The transient comparison with the DCD benchmark feedwater line break results are shown in Figures 5-1 through 5-4. GOTHIC results are the solid line and the DCD data is shown with + markers. The GOTHIC ABWR containment benchmark model matches the DCD results very well. The GOTHIC calculated peak pressure is 53.6 psia. The benchmark model appears to produce slightly higher transient drywell and wetwell pressures. However, as mentioned above, the pressure transient results shown in DCD Figure 6.2-6 appear to be slightly lower than they are stated in DCD Table 6.2-1.

5.2 MAIN STEAM LINE BREAK COMPARISON

The MSLB mass and energy release input data for the benchmark comparison is presented in Figures B-5 and B-6 of Appendix B.

Figures 6.2-12 and 6.2-13 of the DCD were digitized to produce the benchmark pressure and temperature data for comparison with the GOTHIC ABWR containment benchmark model. Please note, the initial suppression pool temperature that is shown in DCD Figure 6.2-13 is lower than the value specified in the text of the DCD (35°C = 95°F). The value that is stated in the text was used as input for the GOTHIC ABWR containment benchmark model.

The transient comparison with the DCD benchmark main steam line break results are shown in Figures 5-5 through 5-8. GOTHIC results are the solid line and the DCD data is shown with + markers. The GOTHIC ABWR containment benchmark model matches the DCD results very well. The GOTHIC calculated peak drywell temperature is 342.2°F. This is slightly higher than the DCD Table 6.2-1 value of 170°C = 338°F. The benchmark model also appears to produce a higher transient suppression pool temperature, but as mentioned above, the initial suppression pool temperature shown in DCD Figure 6.2-13 appears to be lower than the initial pool temperature stated in the DCD text.

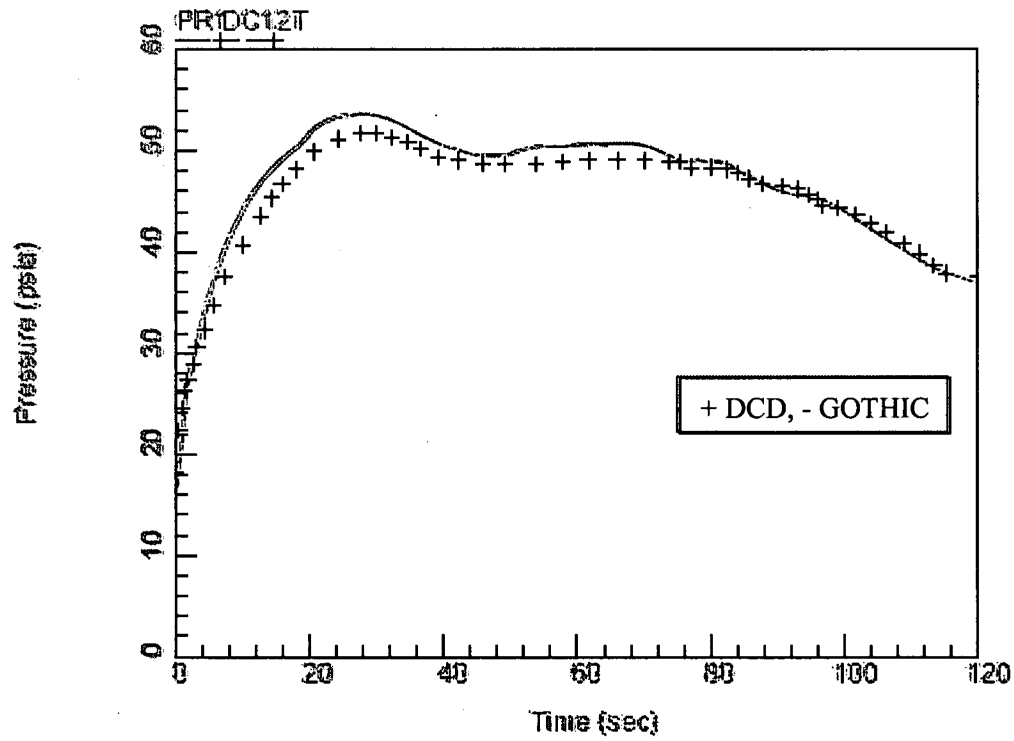

Figure 5-1 FWLB Drywell Pressure Comparison

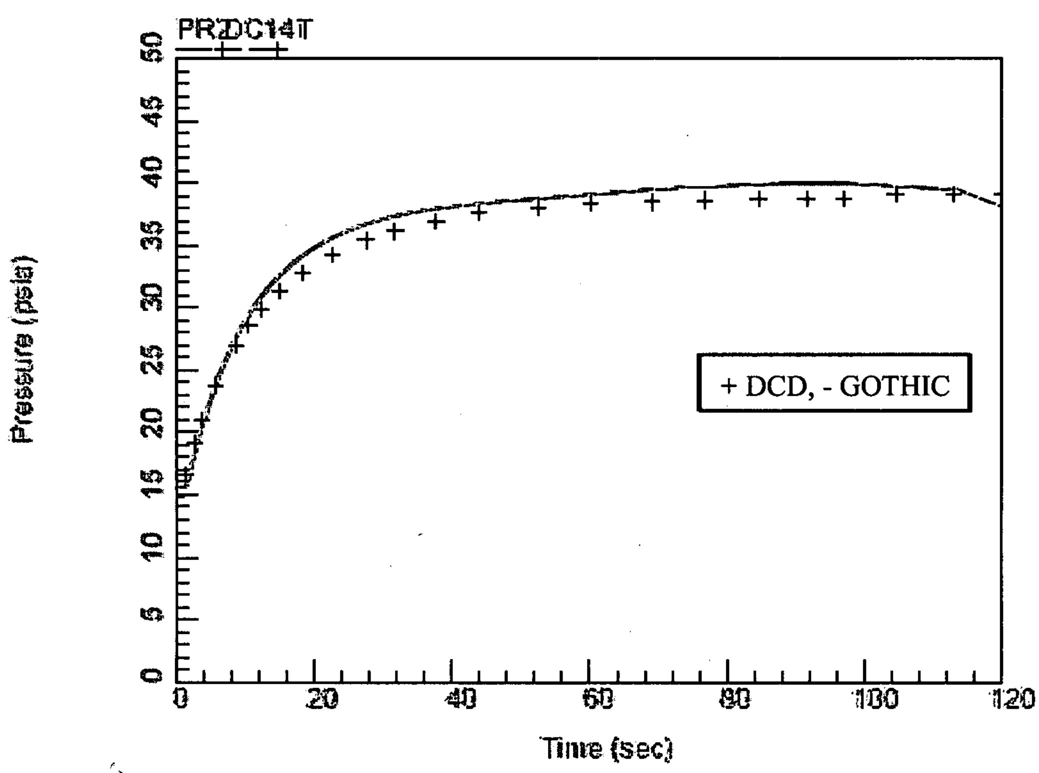

Figure 5-2 FWLB Wetwell Pressure Comparison

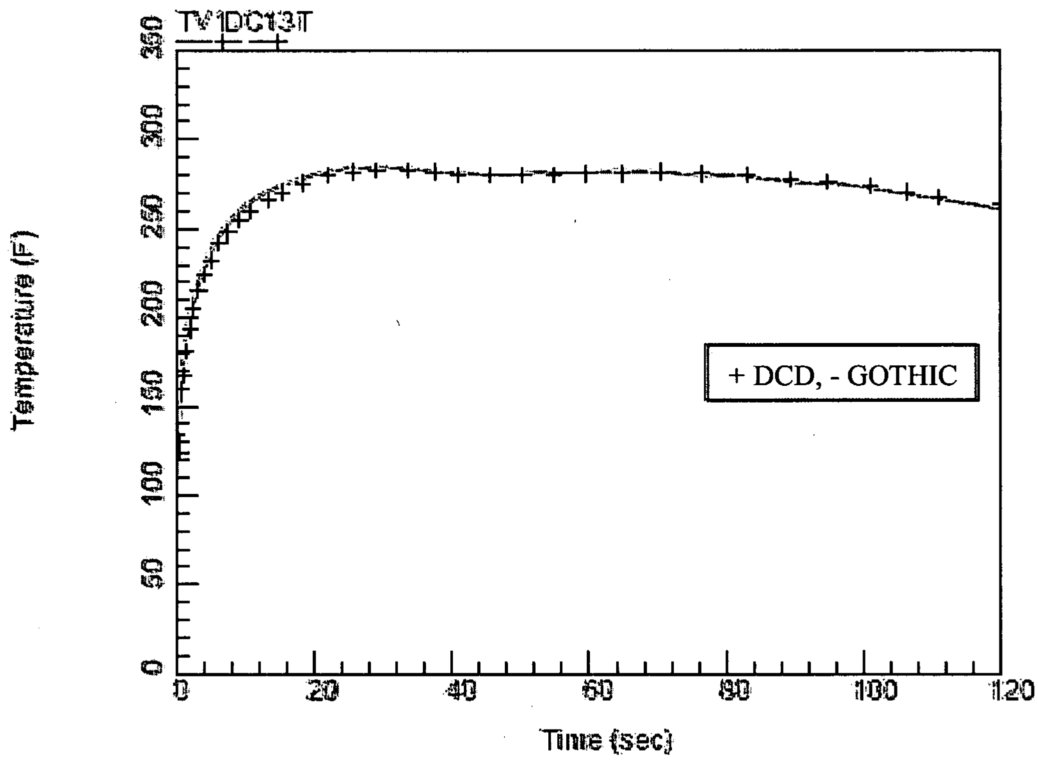

Figure 5-3 FWLB Drywell Temperature Comparison

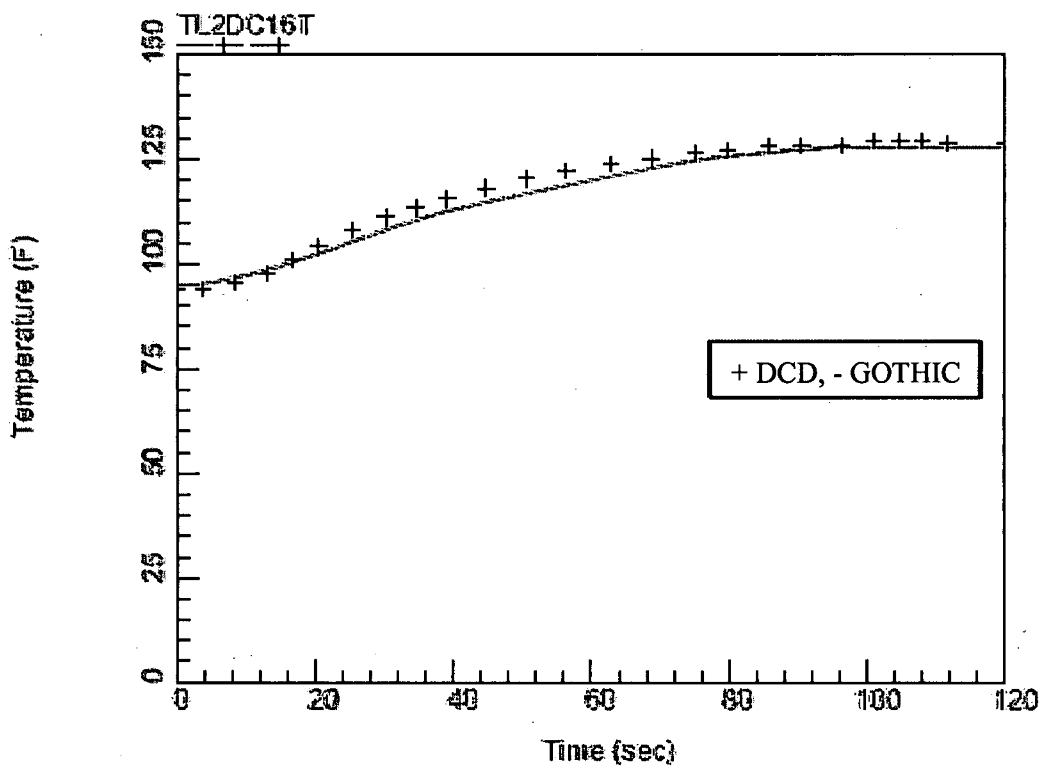

Figure 5-4 FWLB Suppression Pool Temperature Comparison

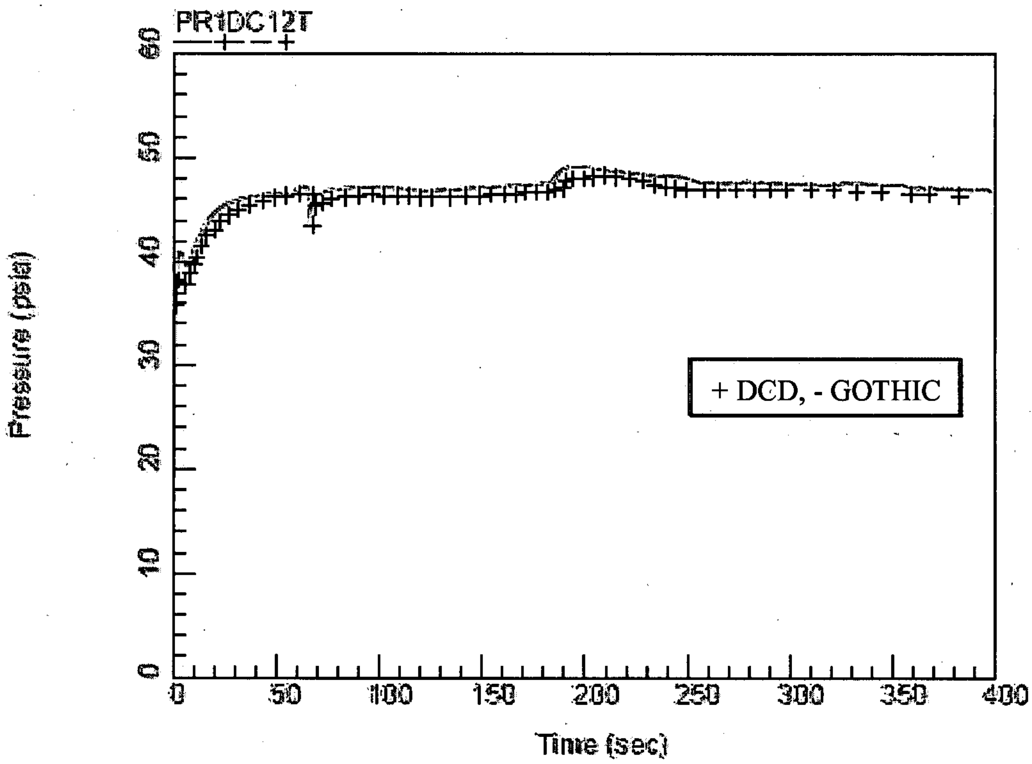

Figure 5-5 MSLB Drywell Pressure Comparison

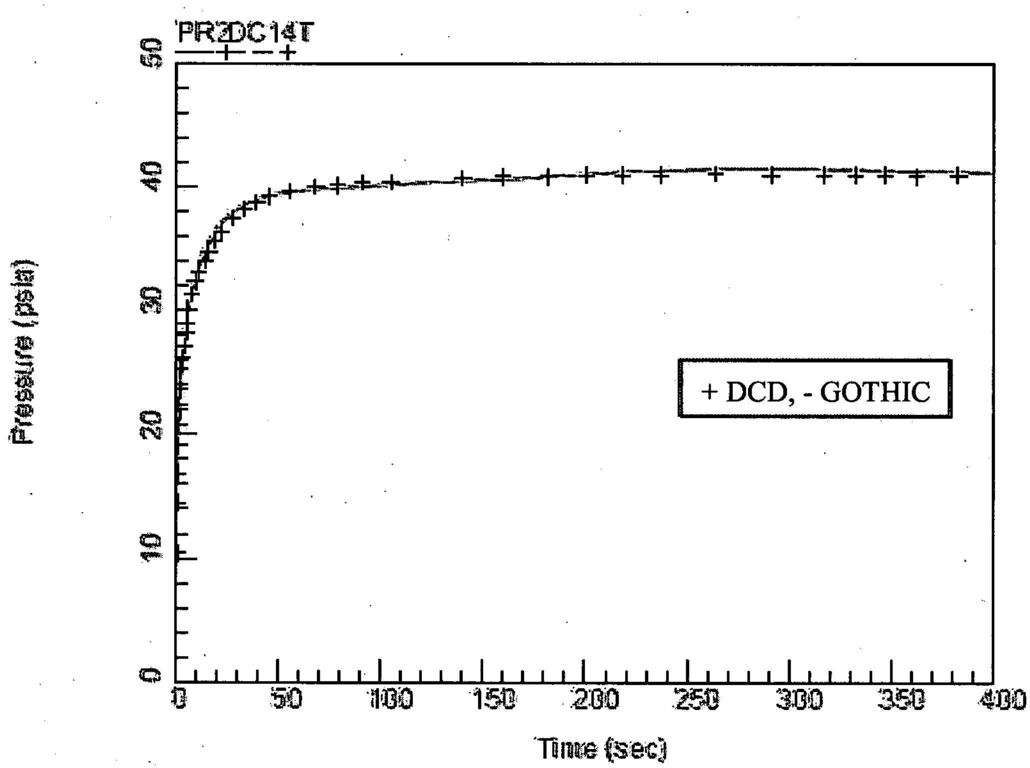

Figure 5-6 MSLB Wetwell Pressure Comparison

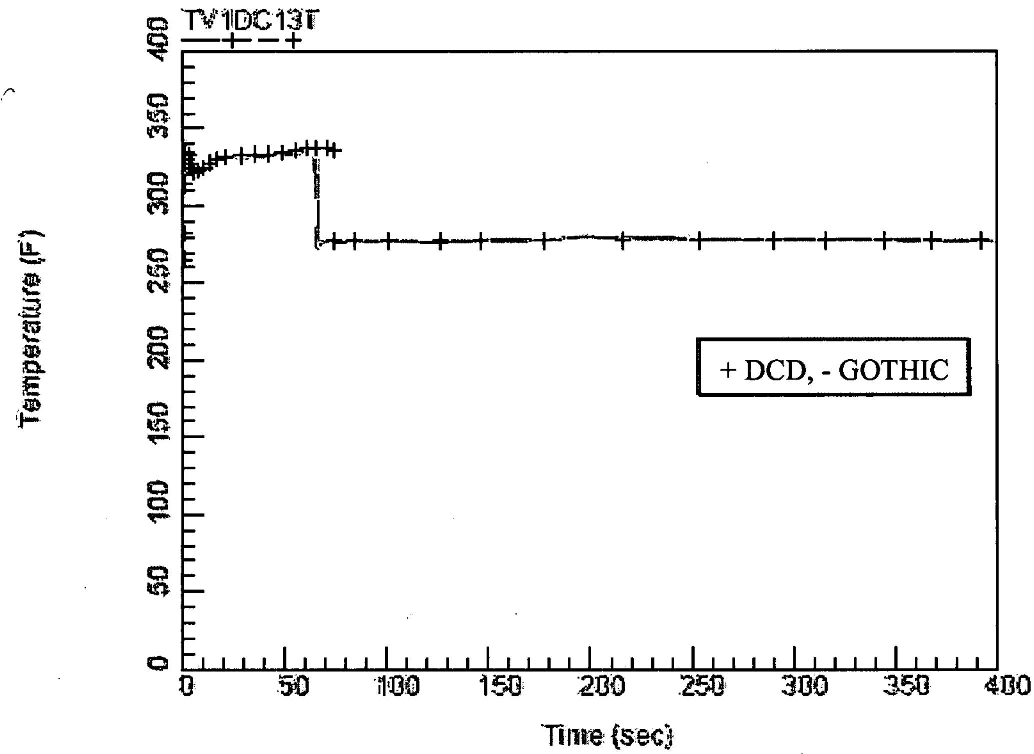

Figure 5-7 MSLB Drywell Temperature Comparison

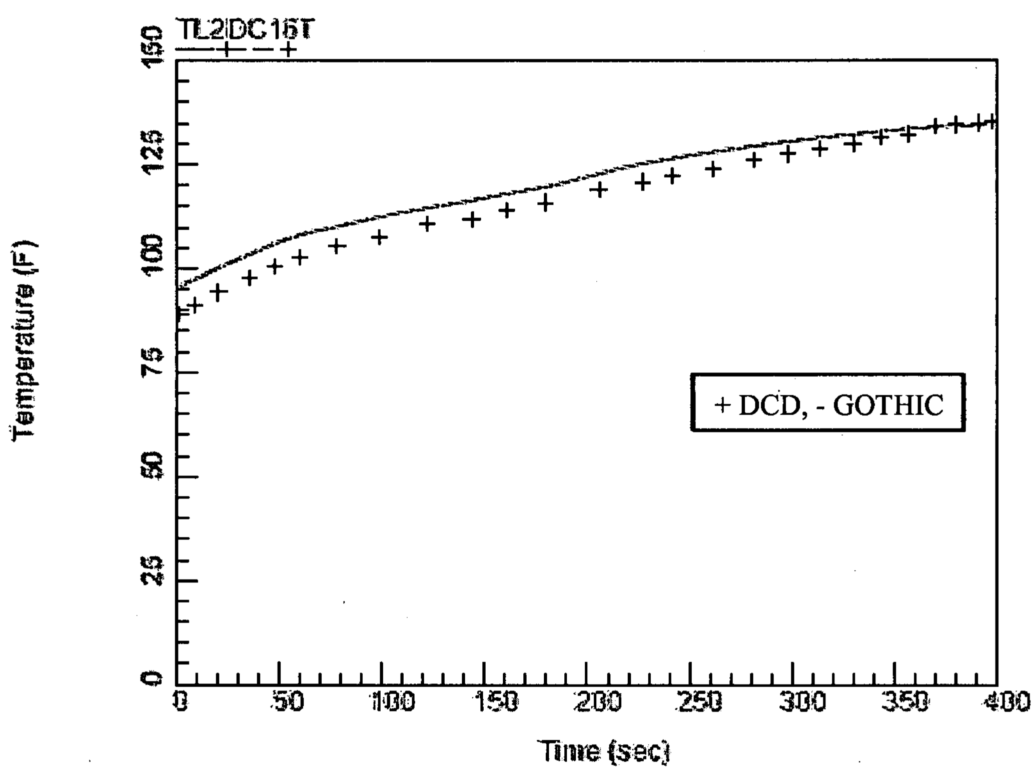

Figure 5-8 MSLB Suppression Pool Temperature Comparison

6 ABWR CONTAINMENT MODELING CORRECTIONS

The GOTHIC ABWR containment benchmark model and associated mass and energy release input calculations were updated to correct the non-conservative modeling assumptions that were identified in Reference 2 for the DCD cases. This section describes the problems and explains how they were modified in the GOTHIC ABWR containment analysis model.

6.1 VENT LOSS COEFFICIENTS

A conservative estimate of the vent loss coefficient is used to calculate the drywell peak pressure. According to Reference 2, the ABWR DCD analyses do not include all of the vent losses between the drywell and the suppression pool. In particular, the reference states that the horizontal vent portion was not simulated properly and the vent clearing time was improperly modeled.

Handbook values (Reference 6) were used to estimate the loss factors, including wall friction, for:

- Drywell connecting vent inlet
- Drywell connecting vent exit
- Vertical vent inlet
- Horizontal vent turning losses
- Horizontal vent exit loss

A loss factor for the trash rack at the entrance to the drywell connecting vent was also included.

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]a,c A range of loss coefficients is provided in the DCD; however, it is not clear how those losses were distributed for the DCD analyses.

6.2 MASS AND ENERGY RELEASES

The break mass and energy release input data is one of the most important contributors in determining the containment response to a LOCA event. According to Reference 2, ABWR containment analyses performed for other plants revealed that the assumptions made in the DCD concerning the FWLB sequence of events, system operation, and maximum flow time interval were non-conservative.

The vessel-side mass and energy releases for the FWLB and MSLB cases were calculated using the Westinghouse BWR LOCA mass and energy release input calculation methodology documented in Reference 5. This reference describes how the Westinghouse BWR ECCS analysis model, which is based on the GOBLIN code, is modified to conservatively calculate the mass and energy releases for the containment analysis. A similar approach was used to modify the ABWR GOBLIN ECCS evaluation model.

Five FWLB cases were run simulating a double-ended rupture of the feedwater line piping inside containment. All of the cases assumed the reactor was operating at 102% power with 111% flow at event initiation time, and offsite power continued to be available throughout the event. In the base case, the reactor internal pumps (RIPs) were not tripped, and the LPFL pump was assumed to be disabled by the location of the break. The second case was similar to the base case except the RCIC pump was disabled by the location of the break. The third case was similar to the base case except the RIPs were tripped at LWL-2. The fourth case was similar to the base case except the RIPs were run back to minimum flow at reactor scram. The fifth case was similar to the fourth case except that the RIPs were tripped at LWL-2.

The vessel-side FWLB mass and energy release calculation results are compared in Figures 6-1 through 6-3. [

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The Westinghouse calculated vessel-side FWLB releases for the peak drywell pressure case are compared with the releases that were used for the DCD benchmark short-term FWLB case; the results are shown in Figures 6-4 and 6-5. The Westinghouse calculated releases are higher than those used for the DCD analysis.

The balance of plant (BOP) side transient break flow rate and enthalpy for the FWLB event are determined from the predicted performance characteristics of a typical ABWR feedwater system. Based on the flow demand sensed by the vessel level control, the feedwater pumps are assumed to runout just after the break occurs. Extraction steam is assumed to continue to be supplied to the feedwater heaters. The feedwater, condensate, and condensate booster pumps are assumed to continue to run. Since offsite power is available, non-safety grade equipment is assumed to continue to operate to provide makeup water from the condensate storage tank. Early termination of the feedwater by the FWLB protection system is not credited. Operator action to terminate feedwater flow is assumed to occur at 30 minutes after event initiation. The resulting BOP-side transient break flow rate and energy curves are compared with the DCD BOP-side break flow and energy curves in Figures 6-6 and 6-7. The new BOP-side mass and energy releases continue for a substantially longer time than those used in the DCD analysis.

Four MSLB cases were run simulating a double-ended rupture of the main steam line inside containment. All of the cases assumed the reactor was operating at 102% power with 111% flow at event initiation time. The base case assumed offsite power was available throughout the event and the feedwater flow rate increased to 130% for the first 10 minutes of the event. The second case was similar to the base case except that the operator was assumed to control the vessel water level near the nominal value by reducing the feedwater flow to 50%. The third case assumed that offsite power was lost at the beginning of the event. Without offsite power, the feedwater and condensate pumps trip and began to coastdown. Fluid in the feedwater line began to flash around 11 seconds in the transient, after the system had depressurized sufficiently. The fourth case was similar to the base case except that the RIPs were runback to minimum speed.

The MSLB mass and energy release calculation results are compared in Figures 6-8 through 6-10. [

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The Westinghouse calculated vessel-side MSLB releases for the peak drywell temperature case are compared with the releases that were used for the DCD benchmark short-term MSLB case; the results are shown in Figures 6-11 and 6-12. The Westinghouse calculated releases are somewhat higher than those used for the DCD analysis.

6.3 DECAY HEAT

A best-estimate decay heat curve (without uncertainty), based on the American National Standards Institute (ANSI)/American Nuclear Society (ANS)-5.1 (1979) decay heat standard, was used for the ABWR DCD mass and energy releases.

Consistent with Reference 5, the ANSI/ANS-5.1 (1979) decay heat standard with 2σ uncertainty is used to calculate the core decay heat rate in the short-term GOBLIN mass and energy release calculation. The tabulated core decay heat fraction for the long-term GOTHIC mass and energy release calculation, which is also based on the ANSI/ANS-5.1 (1979) decay heat standard with 2σ uncertainty, is shown in Table 6-1.

6.4 OTHER CONTAINMENT MODEL INPUT CHANGES

Consistent with the methodology of Reference 5, the liquid/vapor interface area for heat and mass transfer at the wetwell pool surface is set to [

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The initial suppression pool water level was set to the low water level (LWL) value in the ABWR DCD peak pressure analyses. The initial suppression pool water level should be set to the high water level (HWL) value for the peak pressure analysis. This maximizes the vent submergence and minimizes the available gas space in the wetwell. The initial suppression pool water volume was changed from the LWL value to the HWL value to correct this in the updated GOTHIC ABWR containment analysis model for the peak pressure analyses.

The total wetwell volume for the ABWR DCD peak pressure analyses was assumed to be the sum of the minimum pool water volume and minimum air space volume. This was changed to use the sum of the maximum pool water volume and minimum wetwell gas space volume in the updated GOTHIC ABWR containment analysis model.

Table 6-1 ANSI/ANS 5.1-1979 + 2 Sigma Core Decay Heat Fraction	
Time (sec)	**Decay Heat Generation Rate (Btu/Btu)**
10	0.053876
15	0.050401
20	0.048018
40	0.042401
60	0.039244
80	0.037065
100	0.035466
150	0.032724
200	0.030936
400	0.027078
600	0.024931
800	0.023389
1,000	0.022156
1,500	0.019921
2,000	0.018315
4,000	0.014781
6,000	0.013040
8,000	0.012000
10,000	0.011262
15,000	0.010097
20,000	0.009350
40,000	0.007778
60,000	0.006958
80,000	0.006424
100,000	0.006021
150,000	0.005323
200,000	0.004847
400,000	0.003770
600,000	0.003201
800,000	0.002834
1,000,000	0.002580
2,000,000	0.001909
4,000,000	0.001355
6,000,000	0.001091
8,000,000	0.000927
10,000,000	0.000808

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Figure 6-1 FWLB Integrated Break Flow Comparison

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Figure 6-2 FWLB Integrated Break Energy Comparison

a,c

Figure 6-3 FWLB Break Quality

a,c

Figure 6-4 FWLB Vessel Break Flow Rate Comparison

a,c

Figure 6-5 FWLB Vessel Break Energy Comparison

a,c

Figure 6-6 FWLB Pump Break Flow Rate Comparison

a,c

Figure 6-7 FWLB Pump Break Energy Comparison

a,c

Figure 6-8 MSLB Integrated Break Flow Comparison

a,c

Figure 6-9 MSLB Integrated Break Energy Comparison

a,c

Figure 6-10 MSLB Break Quality Comparison

a,c

Figure 6-11 MSLB Break Flow Rate Comparison

a,c

Figure 6-12 MSLB Break Energy Comparison

7 GOTHIC ABWR CONTAINMENT ANALYSIS MODEL SHORT-TERM RESPONSE

This section presents the short-term peak drywell pressure and peak drywell temperature results from the updated GOTHIC ABWR containment analysis model for the limiting FWLB and MSLB events.

7.1 FEEDWATER LINE BREAK

The FWLB case which assumes offsite power is available, the RIPs continue to run, and the LPFL is disabled by the break, results in the highest calculated drywell peak pressure. The mass and energy release data for this limiting FWLB case is presented in Figures B-7 through B-12 of Appendix B.

The short-term containment transient response plots for this limiting FWLB case are shown in Figures 7-1 through 7-4. The break causes a rapid increase in the drywell pressure and temperature. The vents clear shortly after the break occurs, causing the wetwell pressure to increase as air and steam from the drywell are transferred to the wetwell. The calculated drywell peak pressure is 55.58 psia and occurs around 25 seconds into the event. This is approximately 4 psi below the ABWR pressure design limit of 59.67 psia.

7.2 MAIN STEAM LINE BREAK

The MSLB case, which assumes the operator reduces the feedwater flow to control vessel level, results in the highest calculated drywell peak temperature. The mass and energy release data for this limiting MSLB case is presented in Figures B-13 and B-14 of Appendix B.

The short-term containment transient response plots for this limiting MSLB case are shown in Figures 7-5 through 7-8. The break causes a rapid increase in the drywell pressure and temperature. The vents clear shortly after the break occurs, causing the wetwell pressure to increase as air and steam from the drywell are transferred to the wetwell. The drywell peak temperature is 343.8°F and occurs early in the event (around 4 seconds) during the initial steam release. The drywell temperature quickly drops to saturation (about 270°F) after liquid drops begin to be released through the broken steam line.

Although the calculated peak drywell temperature (343.8°F) exceeds the ABWR drywell design temperature (339.8°F) by 4 degrees, the duration of time above the limit is very short (less than 2 seconds). Due to thermal inertia, components in the drywell would not have sufficient time to reach the design limit temperature in this short period of time.

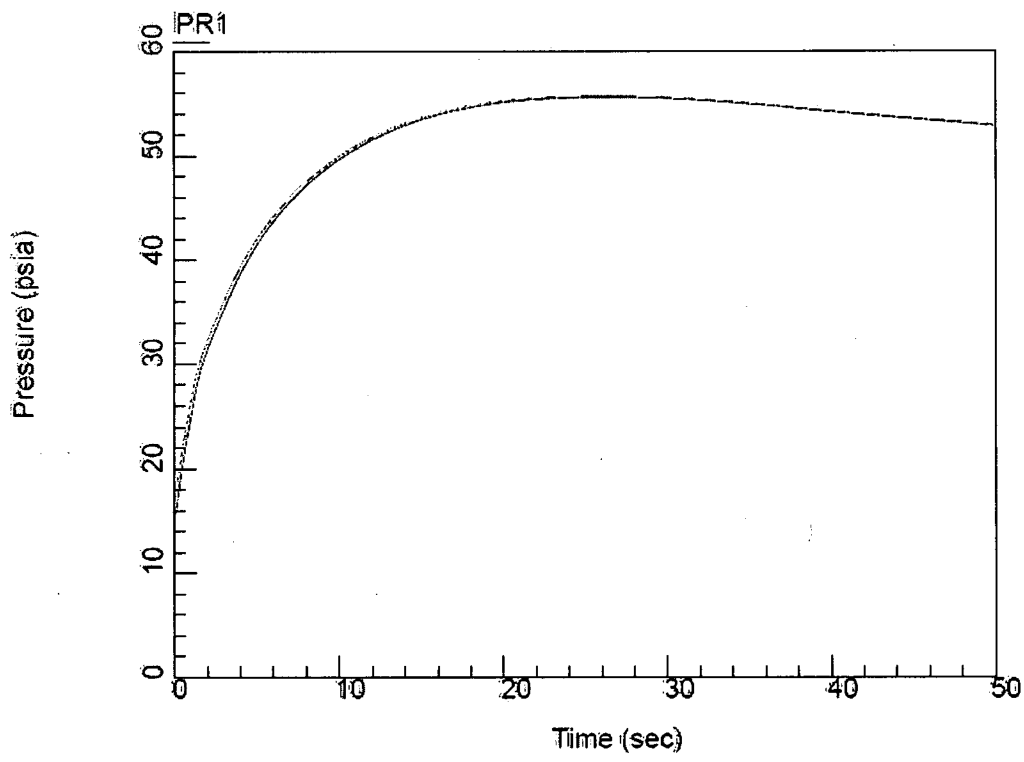

Figure 7-1 FWLB Drywell Pressure

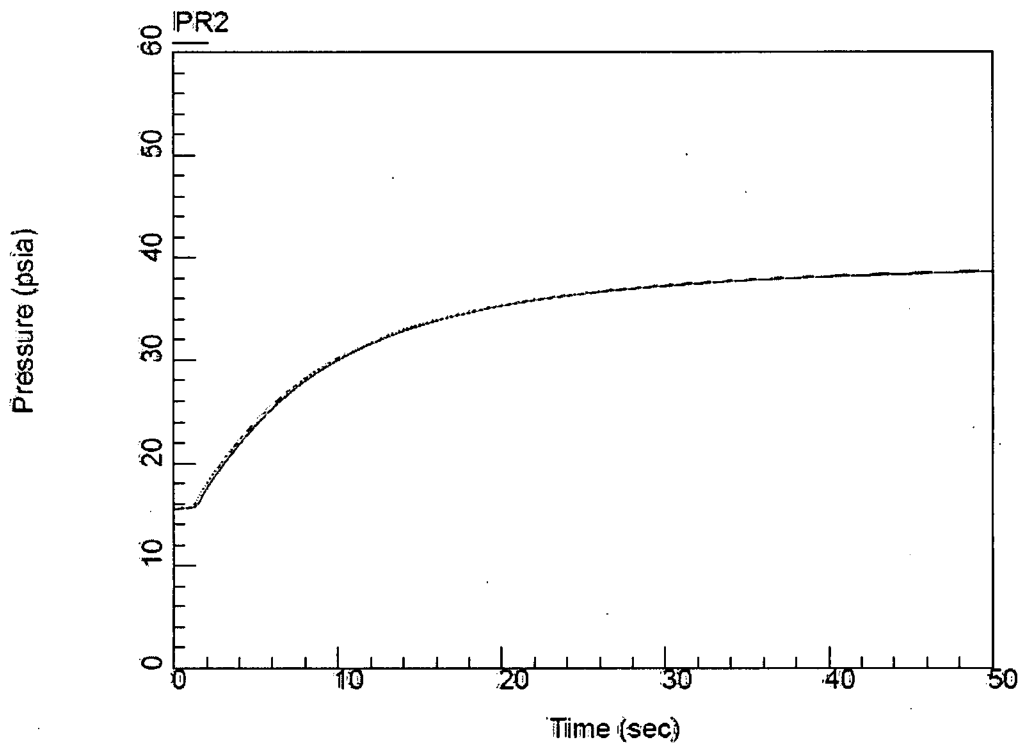

Figure 7-2 FWLB Wetwell Pressure

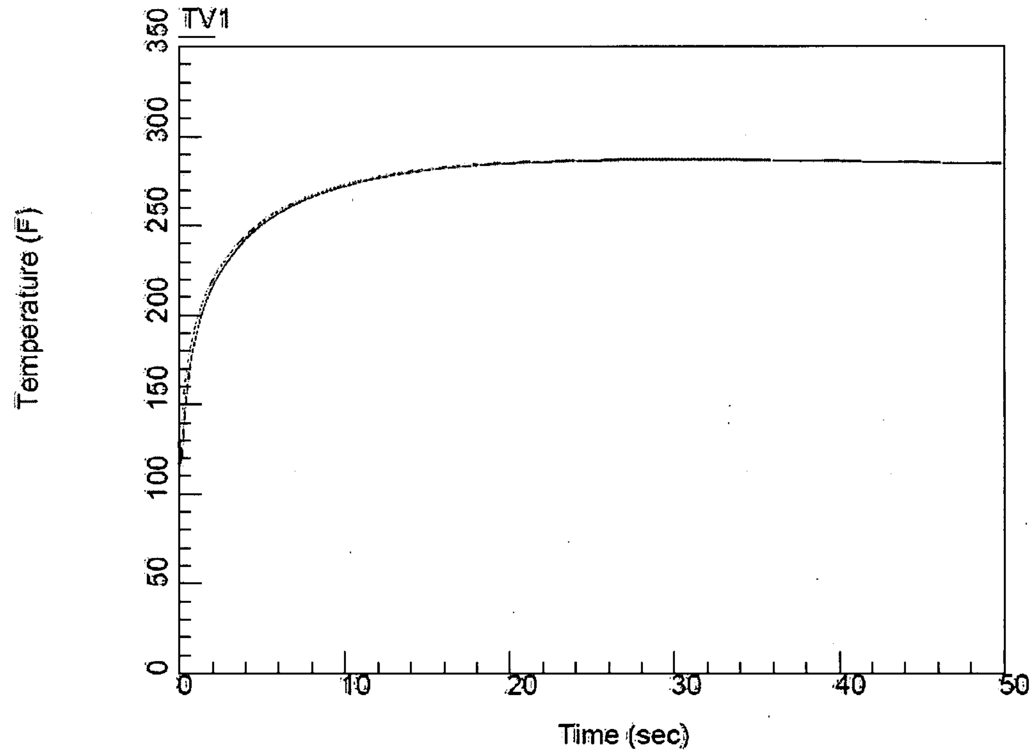

Figure 7-3 FWLB Drywell Temperature

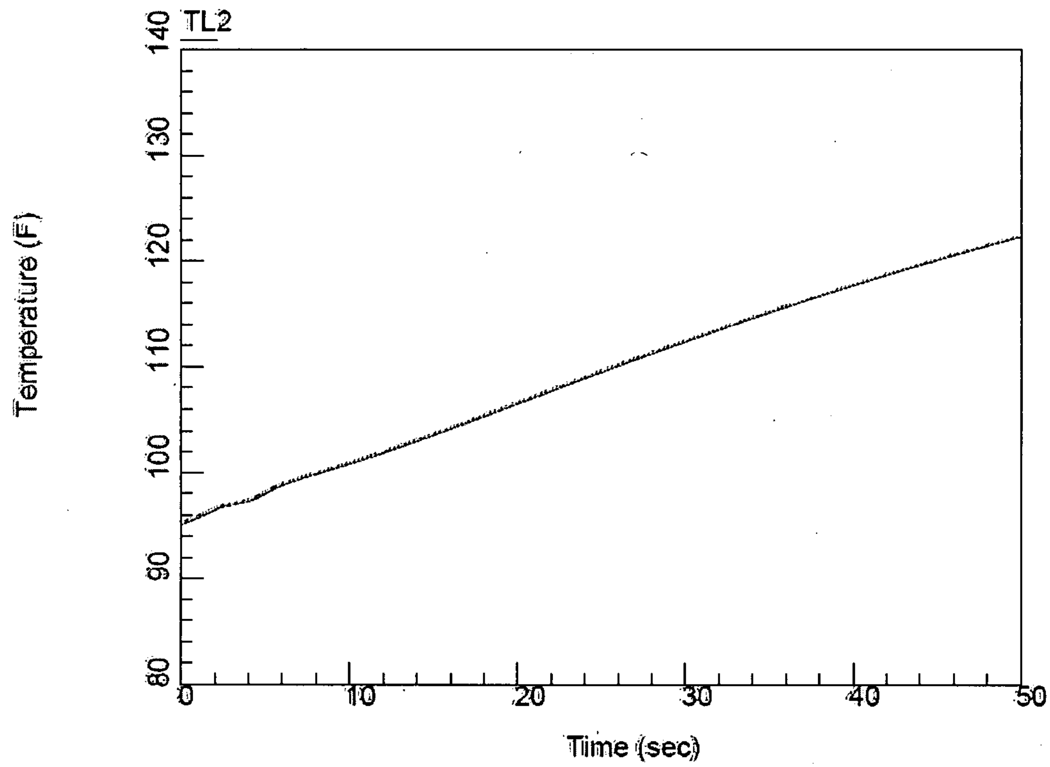

Figure 7-4 FWLB Suppression Pool Temperature

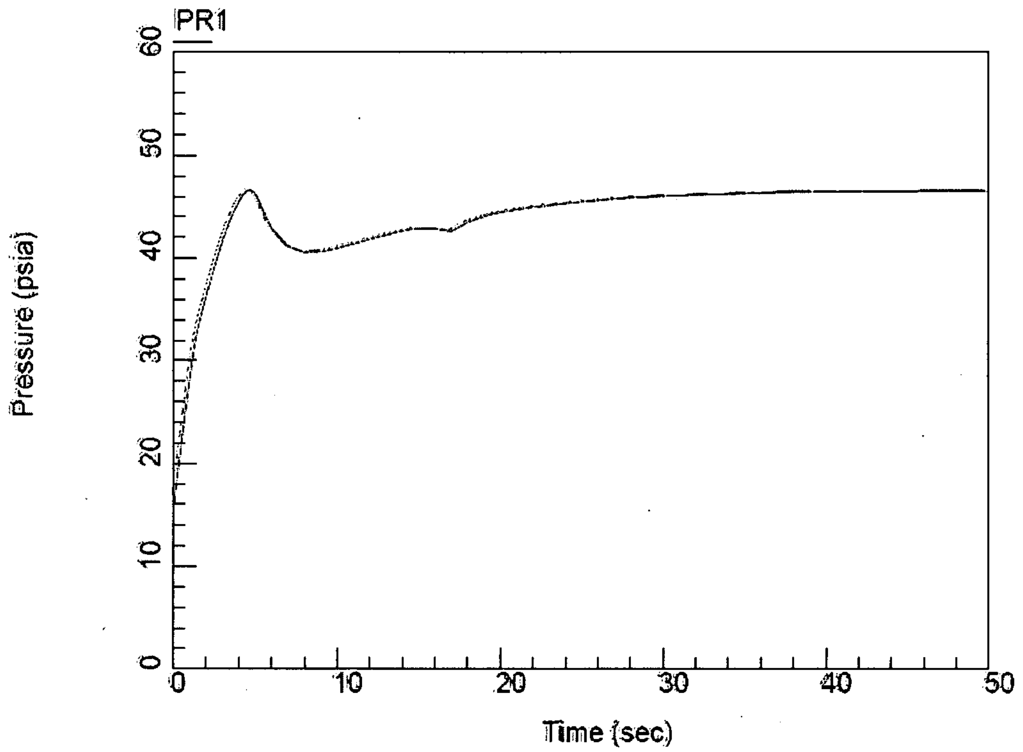

Figure 7-5 MSLB Drywell Pressure

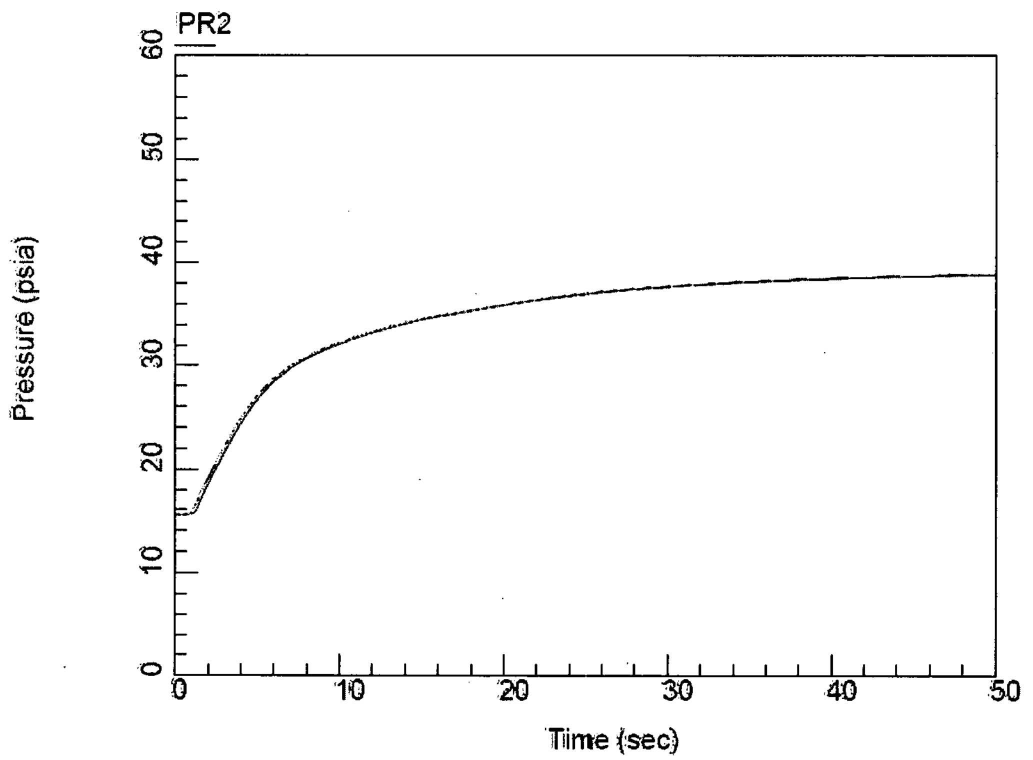

Figure 7-6 MSLB Wetwell Pressure

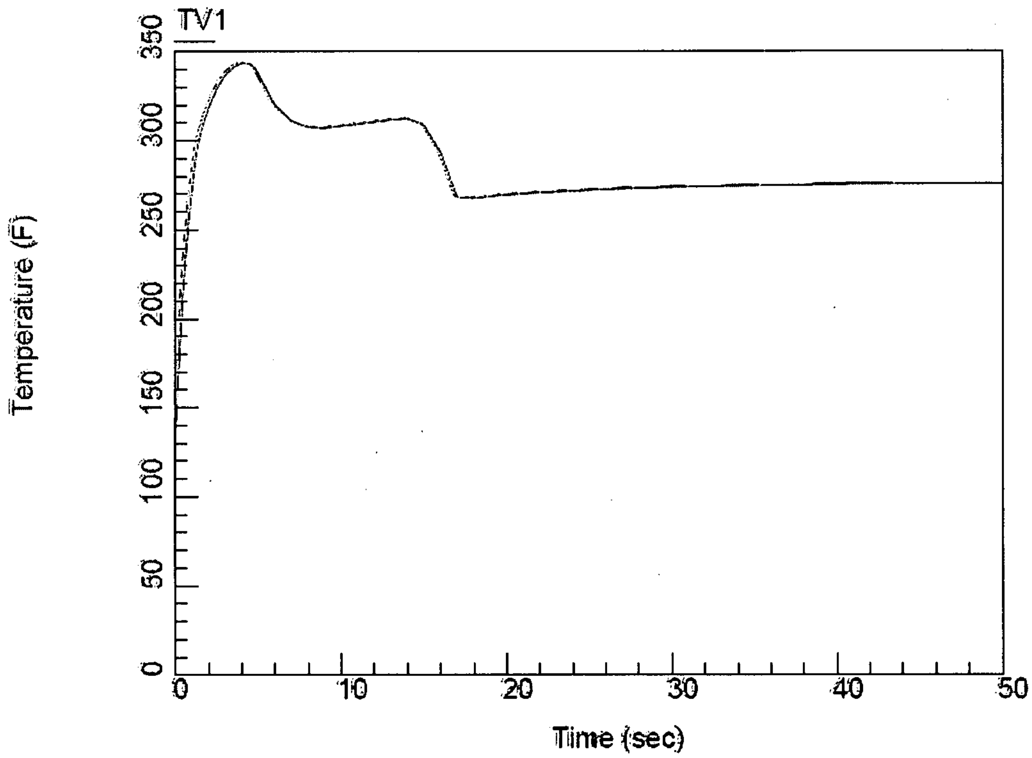

Figure 7-7 MSLB Drywell Temperature

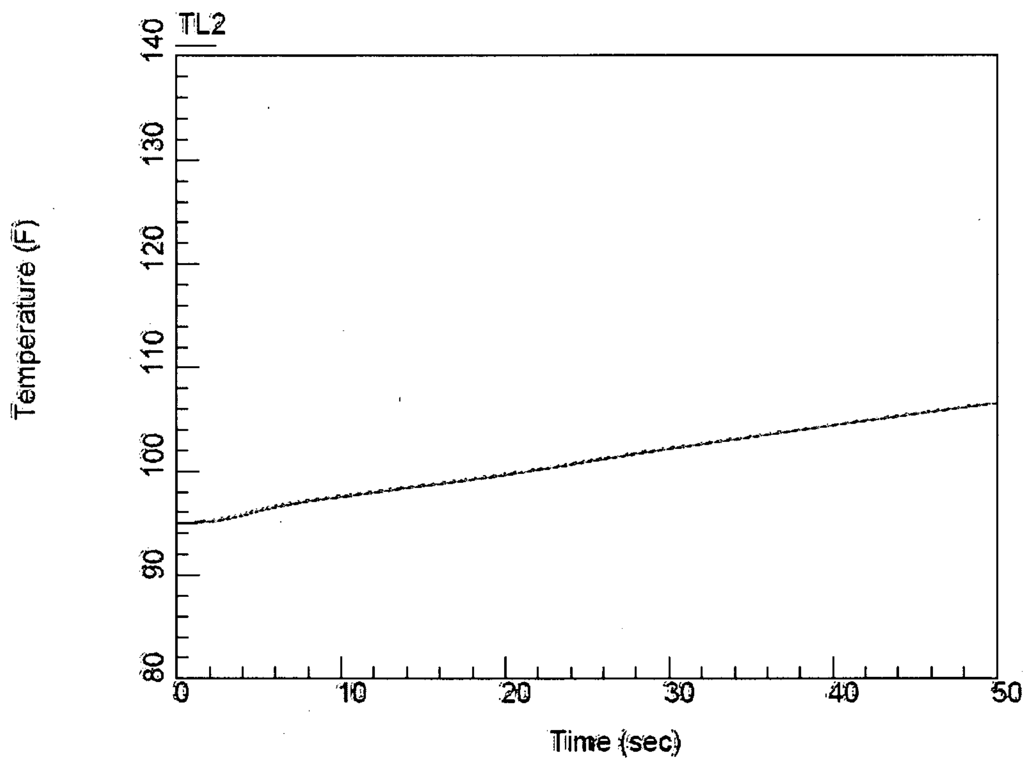

Figure 7-8 MSLB Suppression Pool Temperature

8 GOTHIC ABWR CONTAINMENT ANALYSIS MODEL LONG-TERM RESPONSE

This section describes the GOTHIC ABWR containment analysis model input changes required to generate the transient results for the long-term (peak suppression pool temperature and peak wetwell temperature) cases. The long-term results for the limiting events are presented.

8.1 MODEL INPUT CHANGES

The input for the short-term FWLB and MSLB containment models must be modified for the long-term analyses. The input is biased to calculate a conservatively high pool temperature. The following input changes were made to the GOTHIC ABWR containment analysis model for the long-term analyses:

1. The full lower drywell is used to calculate the drywell volume in both the FWLB and MSLB models because all of the lower drywell gas is expected to be transferred to the wetwell over the long term.

2. The initial suppression pool water level is assumed to be at the minimum value allowed by the ABWR technical specifications (7.0 m) to minimize the pool heat capacity.

3. Some of the hot water that falls down through the drywell connecting vent will spill into the lower drywell; the rest will enter the vertical vent pipe. The lower drywell will eventually fill to the level of the overflow pipes that connect it to the vertical vent pipe. The hot water that resides in the lower drywell can then mix with the suppression pool water through the vertical vent pipe. The time frame for the lower drywell filling and mixing process is unknown. Therefore, a control variable is used to calculate a mixed mean pool water temperature assuming the hot water that settles in the lower drywell is always well mixed with the water in the suppression pool.

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5. Thermal conductors were added to represent various heat sinks inside the containment for consistency with the ABWR DCD.

In addition to the changes listed above, the GOTHIC reactor vessel model is activated to calculate the long-term mass and energy releases after the end of the GOBLIN calculated releases. The GOTHIC reactor vessel model must be initialized before it can be used to generate the long-term releases.

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8.2 FEEDWATER LINE BREAK

None of the feedwater line break cases are limiting for either the peak suppression pool or peak wetwell vapor temperature.

8.3 MAIN STEAM LINE BREAK

The MSLB case which assumes a loss of offsite power results in the highest calculated long-term peak suppression pool and wetwell vapor temperature. The mass and energy release data for this limiting MSLB case is presented in Figures B-15 and B-16 of Appendix B.

The long-term containment transient response plots for the limiting MSLB case are shown in Figures 8-1 through 8-5. Figure 8-4 represents the mixed mean temperature of the water in the lower drywell and suppression pool. The GOTHIC calculated peak mixed mean pool temperature value, 211.2°F, is greater than both the suppression pool temperature design limit (207°F) and the GE calculated value (206.4°F) that are listed in Table 6.2-1 of the DCD. A suppression pool temperature value of 100°C (212°F) is used in the net positive suction head available (NPSHa) calculations, as shown in Tables 6.2-2b and c of the DCD. Therefore, the suppression pool temperature design limit must be clarified for the STP COLA. The calculated peak wetwell vapor temperature is 209.4°F. This is less than the design value (219°F) and slightly less than the calculated value (210°F) reported in DCD Table 6.2-1.

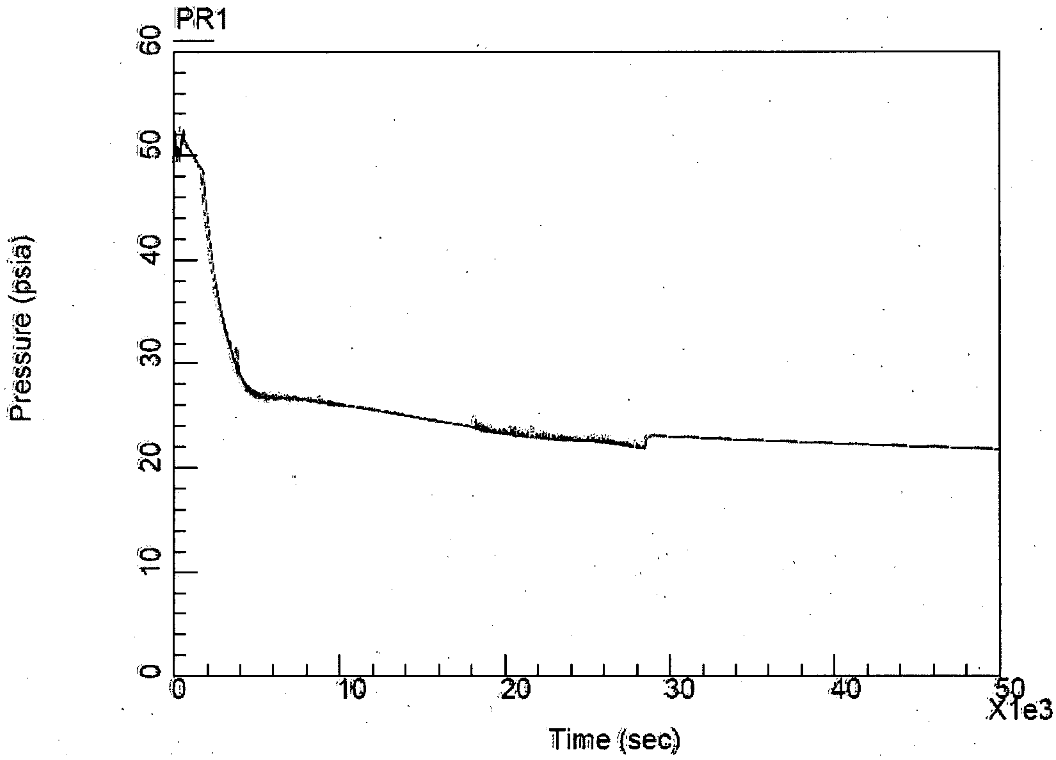

Figure 8-1 MSLB Drywell Pressure

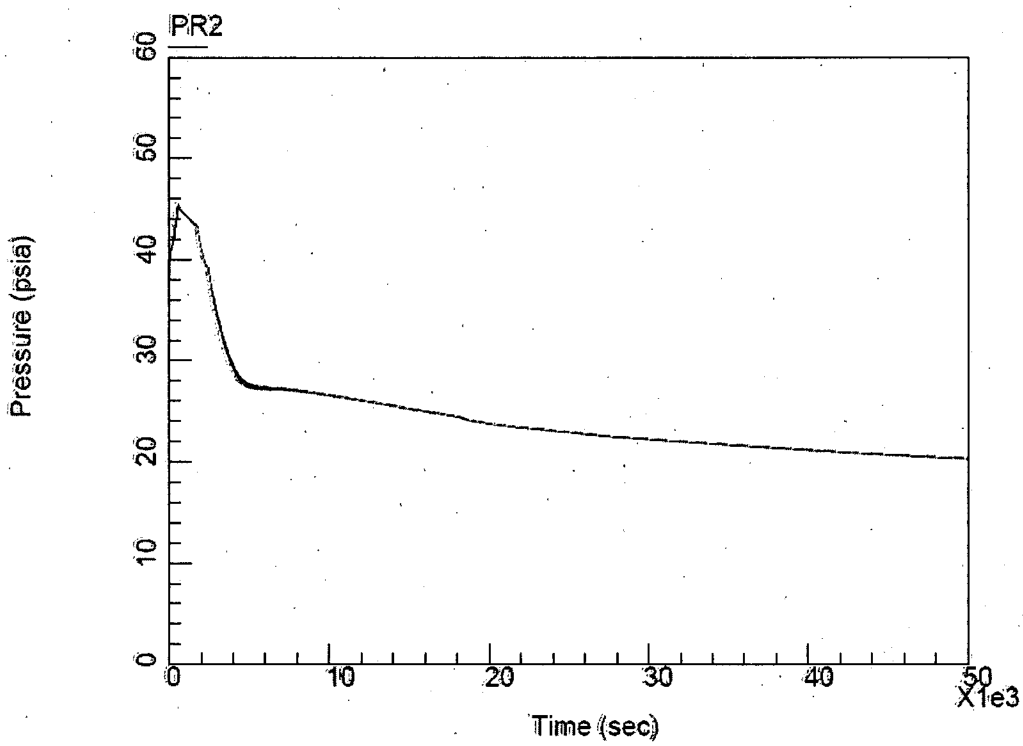

Figure 8-2 MSLB Wetwell Pressure

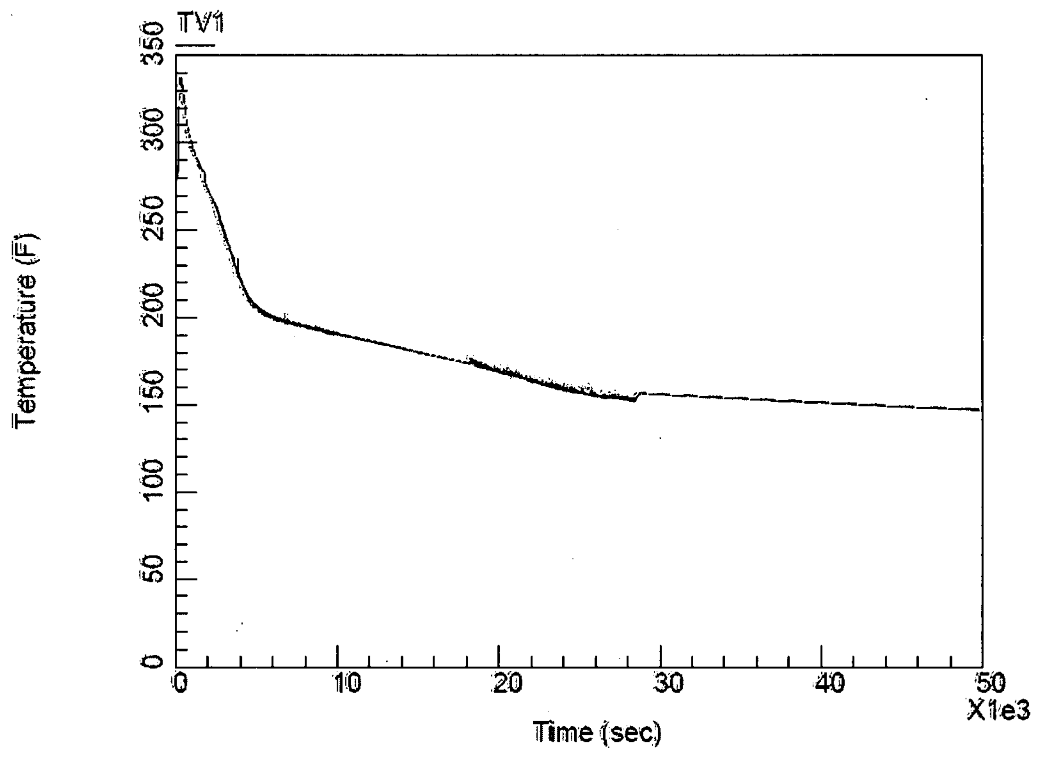

Figure 8-3 MSLB Drywell Temperature

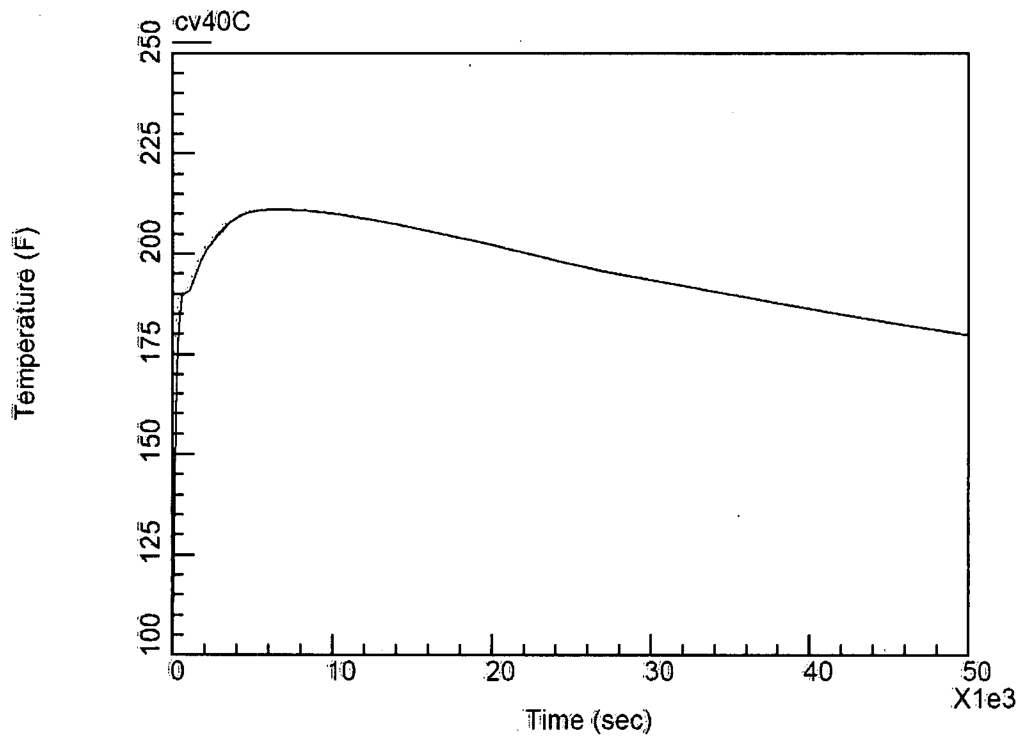

Figure 8-4 MSLB Mixed Mean Pool Temperature

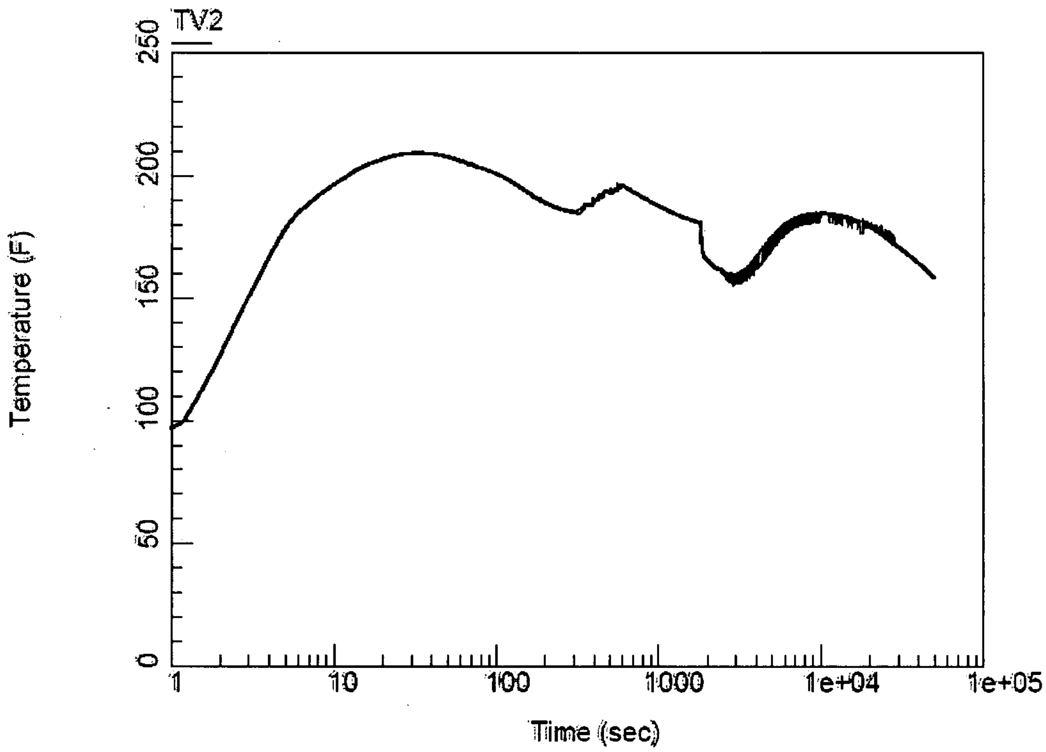

Figure 8-5 MSLB Wetwell Vapor Temperature

9 CONCLUSIONS

An ABWR primary containment model was built using GOTHIC version 7.2a. The model was built to simulate, as much as possible, the approved BWR containment analysis methodology documented in NEDO-20533 (Reference 3) as modified by the ABWR DCD. The GOTHIC modeling methods were compared with the NEDO-20533 and DCD methods to identify the similarities and differences in the three methods.

The GOTHIC ABWR containment model was qualified by comparing its results with the DCD benchmark results for the short-term FWLB and MSLB events. The GOTHIC model results compared well to the ABWR DCD benchmark results. Based on this, the GOTHIC ABWR containment model was determined to be an acceptable alternative for performing the ABWR containment design analyses.

The GOTHIC ABWR containment model was updated to correct several non-conservative modeling assumptions that were identified in the ABWR DCD containment design analysis methodology. The containment design analyses for STP Units 3 and 4 were re-run using this updated model. The containment transient responses for the peak pressure, peak drywell temperature, peak suppression pool temperature, and peak wetwell vapor temperature were presented. The calculated peak drywell temperature and peak suppression pool temperature both exceeded the current design limits listed in the ABWR DCD.

The calculated peak drywell temperature for STP Units 3 and 4 exceeds the design limit for a very short period of time (less than 2 seconds). Due to thermal inertia, components in the drywell would not have sufficient time to reach the design limit temperature in this short period of time. Therefore, the drywell design temperature does not have to be changed for STP Units 3 and 4.

The suppression pool temperature is conservatively calculated as the mixed mean of the lower drywell and wetwell pool temperatures. The suppression pool temperature for STP Units 3 and 4 exceeds the design limit by about 4°F. Therefore, the suppression pool temperature design limit must be increased for the STP COLA.

10 REFERENCES

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2. NEDO-33372, "Advanced Boiling Water Reactor (ABWR) Containment Analysis," September 2007.

3. NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," W. J. Bilanin, June 1974.

4. NAI 8907-02, Rev. 17, "GOTHIC Containment Analysis Package User Manual," Version 7.2a(QA), January 2006.

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

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

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

APPENDIX A
KEY GOTHIC ABWR CONTAINMENT MODEL INPUT PARAMETERS

Table A-1 GOTHIC ABWR Containment Benchmark Model Input Parameters

Geometry	**Values**	
Total Drywell Free Volume		a,c
FWLB	[	]
MSLB	7190.65	m^3
Drywell Height		
FWLB	55.15	m
MSLB	63.1	m
Drywell Inside Diameter	29	m
Number of Vertical Drywell Interconnecting Vents	10	a,c
Flow Area of Each Vertical Drywell Interconnecting Vent	[	]
Height of Vertical Drywell Interconnecting Vent		
Total Vertical Drywell Interconnecting Vent Volume		
Hydraulic Diameter of Vertical Drywell Interconnecting Vent		
Number of Vertical Vent Pipes	10	
Flow Area of Each Vertical Vent Pipe	1.131	m^2 a,c
Height of Vertical Vent Pipe	[	]
Total Vertical Vent Pipe Volume	132.33	m^3
Hydraulic Diameter of Vertical Vent Pipe	1.2	m
		a,c
Number of Horizontal Drywell Overflow Pipes	[	]
Height of Bottom of Drywell Overflow Pipe		
Diameter of Drywell Overflow Pipe		
Area of Drywell Overflow Pipe		
Number of Horizontal Vents per Vent Pipe	3	
Centerline Height of Top Horizontal Vent	3.5	m
Centerline Height of Middle Horizontal Vent	2.13	m
Centerline Height of Bottom Horizontal Vent	0.76	m
Diameter of Each Horizontal Vent	0.7	m
Flow Area of Each Horizontal Vent	0.385	m^2
Wetwell Airspace Free Volume		
HWL	5958	m^3
LWL	N/A	

Table A-1 GOTHIC ABWR Containment Benchmark Model Input Parameters (cont.)		
Geometry (cont.)	**Values**	
Suppression Pool Water Volume		
HWL	N/A	
LWL	3580	m^3
Suppression Pool Depth		
HWL	7.1	m
LWL	7	m
Initial Conditions		
Drywell Pressure	5.2	kPaG
Drywell Temperature	57	C
Drywell Humidity	20	%
Wetwell Pressure	5.2	kPaG
Wetwell Airspace Temperature	35	C
Wetwell Humidity	100	%
Suppression Pool Water Level	LWL	
Suppression Pool Temperature	35	C
ECCS Flow Rates		
Drywell Spray	839	m^3/h
Wetwell Spray	115	m^3/h
LPFL		
RHR	954	m^3/h
RHR Heat Exchanger K Factor (2 of 3)	740.7	kJ/s-C
Service Water Temperature(1)	35	C

Note:
1. This is the Tech Spec upper limit for the service water temperature at the RHR heat exchanger inlet.

Table A-1 GOTHIC ABWR Containment Benchmark Model Input Parameters (cont.)	
Special Modeling Techniques	**Values**

a,c

Table A-2 GOTHIC ABWR Containment Analysis Model Input Parameters

(Changes are highlighted)

Geometry	**Values**	
Total Drywell Free Volume		a,c
FWLB	[ ]	
MSLB	7190.65	m^3
Drywell Height		
FWLB	55.15	m
MSLB	63.1	m
Drywell Inside Diameter	29	m
Number of Vertical Drywell Interconnecting Vents	10	a,c
Flow Area of Each Vertical Drywell Interconnecting Vent	[	
Height of Vertical Drywell Interconnecting Vent		
Total Vertical Drywell Interconnecting Vent Volume		
Hydraulic Diameter of Vertical Drywell Interconnecting Vent	]	
Number of Vertical Vent Pipes	10	
Flow Area of Each Vertical Vent Pipe	1.131	m^2 a,c
Height of Vertical Vent Pipe	[ ]	
Total Vertical Vent Pipe Volume	132.33	m^3
Hydraulic Diameter of Vertical Vent Pipe	1.2	m
		a,c
Number of Horizontal Drywell Overflow Pipes	[	
Height of Bottom of Drywell Overflow Pipe		
Diameter of Drywell Overflow Pipe		
Area of Drywell Overflow Pipe	]	
Number of Horizontal Vents per Vent Pipe	3	m
Centerline Height of Top Horizontal Vent	3.5	m
Centerline Height of Middle Horizontal Vent	2.13	m
Centerline Height of Bottom Horizontal Vent	0.76	m
Diameter of Each Horizontal Vent	0.7	m
Flow Area of Each Horizontal Vent	0.385	m^2
Wetwell Airspace Free Volume		
HWL	5958	m^3
LWL	6003	m^3

Table A-2 GOTHIC ABWR Containment Analysis Model Input Parameters (cont.)		
Geometry (cont.)	**Values**	
Suppression Pool Water Volume		
HWL	3625	m^3
LWL	3580	m^3
Suppression Pool Depth		
HWL	7.1	m
LWL	7	m
Initial Conditions		
Drywell Pressure	5.2	kPaG
Drywell Temperature	57	C
Drywell Humidity	20	%
Wetwell Pressure	5.2	kPaG
Wetwell Airspace Temperature	35	C
Wetwell Humidity	100	%
Suppression Pool Water Level	HWL	
Suppression Pool Temperature	35	C
ECCS Flow Rates		
Drywell Spray	839	m^3/h
Wetwell Spray	115	m^3/h
LPFL		
RHR	954	m^3/h
		a,c
RHR Heat Exchanger K Factor (2 of 3)	[	]
Service Water Temperature(1)	35	C

Note:
1. This is the Tech Spec upper limit for the service water temperature at the RHR heat exchanger inlet.

Table A-2 (cont.) GOTHIC ABWR Containment Analysis Model Input Parameters	
Special Modeling Techniques	**Values**

a,c

APPENDIX B
BREAK MASS AND ENERGY RELEASE INPUT

a,c

Figure B-1 DCD Benchmark FWLB Vessel Break Flow Rate

a,c

Figure B-2 DCD Benchmark FWLB Vessel Break Energy

a,c

Figure B-3 DCD Benchmark FWLB Pump Break Flow Rate

a,c

Figure B-4 DCD Benchmark FWLB Pump Break Energy

a,c

[ ]

Figure B-5 DCD Benchmark MSLB Total Break Flow Rate

a,c

[ ]

Figure B-6 DCD Benchmark MSLB Total Break Energy

a,c

Figure B-7 FWLB Vessel Break Flow Rate

a,c

Figure B-8 FWLB Vessel Break Energy

a,c

Figure B-9 FWLB ADS Break Flow Rate

a,c

Figure B-10 FWLB ADS Break Energy

a,c

Figure B-11 FWLB Pump Break Flow Rate

a,c

Figure B-12 FWLB Pump Break Energy

a,c

Figure B-13 MSLB Total Break Flow Rate (Peak Drywell Temperature Case)

a,c

Figure B-14 MSLB Total Break Energy (Peak Drywell Temperature Case)

a,c

[ ]

Figure B-15 MSLB Total Break Flow Rate (Peak Pool and Wetwell Temperature Case)

a,c

[ ]

Figure B-16 MSLB Total Break Energy (Peak Pool and Wetwell Temperature Case)