PMSTPCOL NPEmails

From: Joseph, Stacy
Sent: Friday, September 25, 2009 8:37 AM
To: Drozd, Andrzej
Cc: STPCOL
Subject: PROPRIETARY - STP Pool Swell Report
Attachments: U7-C-STP-NRC-090142.pdf

Andrzej,

Please see the attached Pool Swell Report. Please note that it is PROPRIETARY so please handle as such.

Thank you,
Stacy

From: Scheide Richard [mailto:rhscheide@STPEGS.COM]
Sent: Thursday, September 24, 2009 5:44 PM
To: Joseph, Stacy
Subject:

Stacy,

Attached is a copy of the Pool Swell report submittal.

Dick Scheide
Office: 361-972-7336
Cell: 479-970-9026

Hearing Identifier: SouthTexas34NonPublic_EX
Email Number: 1782

Mail Envelope Properties (CEEA97CC21430049B821E684512F6E5ECA804E0313)

Subject: PROPRIETARY - STP Pool Swell Report
Sent Date: 9/25/2009 8:36:56 AM
Received Date: 9/25/2009 8:36:57 AM
From: Joseph, Stacy

Created By: Stacy.Joseph@nrc.gov

Recipients:
"STPCOL" <STP.COL@nrc.gov>
Tracking Status: None
"Drozd, Andrzej" <Andrzej.Drozd@nrc.gov>
Tracking Status: None

Post Office: HQCLSTR01.nrc.gov

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[redacted]

STP Nuclear Operating Company

South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

September 24, 2009
U7-C-STP-NRC-090142

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Transmittal of Toshiba Pool Swell Report

Attached is a technical report prepared by Toshiba Corporation in support of the STP 3 and 4 Combined License Application. The topical report is entitled "Post LOCA Suppression Pool Swell Analysis for ABWR Containment Design," UTLR-0005-P Rev.0. Also attached is a non-proprietary version of this same report, UTLR-0005-NP Rev.0.

Since this report contains information proprietary to Toshiba Corporation and Westinghouse Electric Company LLC, it is supported by two affidavits signed by the respective companies. The affidavits set 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 Section 2.390 of the Commission's regulations.

Accordingly, it is respectfully requested that the information which is proprietary to Toshiba and Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Attachment 1 contains the proprietary version of the report. Attachment 2 contains the request for withholding of proprietary information and affidavit for Toshiba Corporation. Attachment 3 contains the affidavit for Westinghouse Electric Company, LLC, the proprietary information notice, and the copyright notice. Attachment 4 contains the non-proprietary version of the report.

When separated from the proprietary material, this letter is not proprietary.

There are no commitments in this letter.

If you have any questions regarding this report, please contact Scott Head at (361) 972-7136, or Bill Mookhoek at (361) 972-7274. Correspondence with respect to the proprietary aspects of the report should be addressed to B.F. Maurer, Manager, ABWR Licensing, Westinghouse Electric LLC, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 9/24/2009

Mark McBurnett
Vice President, Oversight & Regulatory Affairs
South Texas Project Units 3 & 4

jet

Attachments:

1. UTLR-0005-P Rev. 0 (proprietary version)
2. Toshiba Corporation Affidavit
3. Westinghouse Electric Company LLC Affidavit
4. UTLR-0005-NP Rev. 0 (non-proprietary version)

cc: w/o attachment except*
(paper copy)

Director, Office of New Reactors
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Regional Administrator, Region IV
U. S. Nuclear Regulatory Commission
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Steve Winn
Eddy Daniels
Joseph Kiwak
Nuclear Innovation North America

Jon C. Wood, Esquire
Cox Smith Matthews

J. J. Nesrsta
R. K. Temple
Kevin Pollo
L. D. Blaylock
CPS Energy

Affidavit for Withholding Confidential and Proprietary Information from Public Disclosure under 10 CFR § 2.390

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of

STP Nuclear Operating Company

Docket Nos.52-012
52-013

South Texas Project
Units 3 and 4

AFFIDAVIT

I, Kenji Arai, being duly sworn, hereby depose and state that I am Senior Manager, System Design & Engineering Department, Nuclear Energy Systems & Services Division, Power Systems Company, Toshiba Corporation; that I am duly authorized by Toshiba Corporation to sign and file with the Nuclear Regulatory Commission the following application for withholding Toshiba Corporation's confidential and proprietary information from public disclosure; that I am familiar with the content thereof; and that the matters set forth therein are true and correct to the best of my knowledge and belief.

In accordance with 10 CFR § 2.390(b)(ii), I hereby state, depose, and apply as follows on behalf of Toshiba Corporation:

(A) Toshiba Corporation seeks to withhold from public disclosure the document entitled and identified as "Post LOCA Suppression Pool Swell Analysis for ABWR Containment Design," Revision 0, UTLR-0005-P(Proprietary), and all information identified as "Toshiba Proprietary Information Class 2" therein (collectively, "Confidential Information").

(B) The Confidential Information is owned by Toshiba Corporation. In my position as Senior Manager, System Design & Engineering Department, Nuclear Energy Systems & Services Division, Power System Company, Toshiba Corporation, I have been specifically delegated the function of reviewing the Confidential Information and have been authorized to apply for its withholding on behalf of Toshiba Corporation.

(C) This document is the additional information of hydrodynamic (pool swell) load evaluation for South Texas Project Units 3&4 Combined License Application to the Nuclear Regulatory Commission. The Confidential Information which is entirely confidential and proprietary to Toshiba Corporation is indicated in the document using brackets.

(D) Consistent with the provisions of 10 CFR § 2.390(a)(4), the basis for proposing that the Confidential Information be withheld is that it constitutes Toshiba Corporation's trade secrets and confidential and proprietary commercial information.

(E) Public disclosure of the Confidential Information is likely to cause substantial harm to Toshiba Corporation's competitive position by (1) disclosing confidential and proprietary commercial information about the design, manufacture and operation systems for nuclear power reactors to other parties whose commercial interests may be adverse to those of Toshiba Corporation, and (2) giving such parties access to and use of such information at little or no cost, in contrast to the significant costs incurred by Toshiba Corporation to develop such information.

Further, on behalf of Toshiba Corporation, I affirm that:

(i) The Confidential Information is confidential and proprietary information of Toshiba Corporation.

(ii) The Confidential Information is information of a type customarily held in confidence by Toshiba Corporation, and there is a rational basis for doing so given the sensitive and valuable nature of the Confidential Information as discussed above in paragraphs (D) and (E).

(iii) The Confidential Information is being transmitted to the NRC in confidence.

(iv) The Confidential Information is not available in public sources.

(v) Public disclosure of the Confidential Document is likely to cause substantial harm to the competitive position of Toshiba Corporation, taking into account the value of the Confidential Information to Toshiba Corporation, the amount of money and effort expended by Toshiba Corporation in developing the Confidential Information, and the ease or difficulty with which the Confidential Information could be properly acquired or duplicated by others.

Kenji Arai
Senior Manager
System Design & Engineering Department
Nuclear Energy Systems & Services Division
POWER SYSTEMS COMPANY
TOSHIBA CORPORATION

Sept. 16, 2009
Date

平成２１年登簿第　159　号

認　　証

嘱託人株式会社東芝部長新井健司は、公証人の面前で、添付書面に署名した。

よって、これを認証する。

平成２１年　9　月　16　日、本公証人役場において

横浜市中区羽衣町2丁目7番10号

横浜地方法務局所属

公　証　人

Notary

KENJI　TERANISHI

証　　明

上記署名は、横浜地方法務局所属公証人の署名に相違ないものであり、かつ、その押印は、真実のものであることを証明する。

平成２１年　9　月　16　日

横浜地方法務局長　紺野清幸

APOSTILLE

(Convention de La Haye du 5 octobre 1961)

1. Country : JAPAN
   This public document
2. has been signed by KENJI TERANISHI
3. acting in the capacity of Notary of the Yokohama District Legal Affairs Bureau
4. bears the seal/stamp of KENJI TERANISHI , Notary

Certified

5. at Tokyo　　6. SEP. 16. 2009
7. by the Ministry of Foreign Affairs
8. 09-№ 300568
9. Seal/stamp :　　10.Signature :

MINISTRY OF FOREIGN AFFAIRS JAPAN

Kazutoyo OYABE

For the Minister for Foreign Affairs

Registered No. 159 of 2009.

Certificate of Acknowledgment of Notary

On this 16th day of September, 2009, before me, KENJI TERANISHI, a notary in and for YOKOHAMA District Legal Affairs Bureau, appeared Kenji ARAI, Senior Manager of TOSHIBA Corporation, who is personally known to me, affixed his signature to the attached document.

Witness, I set my hand and seal.

Notary

Notary's seal (Official)

KENJI TERANISHI

Kannai-odori Notary office

2-7-10, Hagoromocho, Naka-ku, Yokohama-city, Japan.

Attached to the Yokohama District Legal Affairs Bureau.

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 14th day of September, 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, UTLR-0005-P, "Post LOCA Suppression Pool Swell Analysis for ABWR Containment Design" (Proprietary) for submittal to the Commission, being transmitted by South Texas Project Nuclear Operating Company (STPNOC) letter to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with the review of the ABWR suppression pool swell analysis methodology and 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.
(b) Obtain NRC review of the Westinghouse ABWR suppression pool swell analysis methodology.

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 pool swell 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

The reports transmitted herewith each bear a Westinghouse copyright notice. The NRC is permitted to make the number of copies of the information contained in these reports which are necessary for its internal use in connection with generic and plant-specific reviews and approvals as well as the issuance, denial, amendment, transfer, renewal, modification, suspension, revocation, or violation of a license, permit, order, or regulation subject to the requirements of 10 CFR 2.390 regarding restrictions on public disclosure to the extent such information has been identified as proprietary by Westinghouse, copyright protection notwithstanding. With respect to the non-proprietary versions of these reports, the NRC is permitted to make the number of copies beyond those necessary for its internal use which are necessary in order to have one copy available for public viewing in the appropriate docket files in the public document room in Washington, DC and in local public document rooms as may be required by NRC regulations if the number of copies submitted is insufficient for this purpose. Copies made by the NRC must include the copyright notice in all instances and the proprietary notice if the original was identified as proprietary.

TOSHIBA

Post LOCA Suppression Pool Swell Analysis

for ABWR Containment Design

September 2009

Toshiba Corporation

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This document contains information intended to support ABWR licensing activities by TOSHIBA CORPORATION. The use of the information contained in this document by anyone for any purpose other than that for which it is intended is not authorized. In the event the information is used without authorization from TOSHIBA CORPORATION, TOSHIBA CORPORATION makes no representation or warranty and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

TOSHIBA CORPORATION

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1 Introduction and Background

The Nuclear Regulatory Commission (NRC) in July 1994 issued the Final Safety Evaluation Report (FSER) to an application for the final design approval (FDA) and standard design certification for the advanced boiling water reactor (ABWR) [1]. In March 1997, revision 4 of the ABWR Design Control Document (DCD) was submitted. The NRC granted final design certification for the ABWR in June 1997.

NRG Energy/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.

In September 2007, GE submitted licensing topical report (LTR) NEDO-33372 [2] for NRC review. 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 for assistance with the licensing and analysis support effort for the South Texas ABWR plants.

In June 2009, Westinghouse submitted a post-LOCA containment pressure and temperature analysis method for the ABWR containment design [9], reflecting the corrections and improvement identified in [2]. The Westinghouse method is based on the GOTHIC computer code [3-5].

2 Purpose

Appendix 3B of the ABWR DCD describes the methodology used to define hydrodynamic loads inside the primary containment of an ABWR during Safety Relief Valve (SRV) actuation and a Loss of Coolant Accident (LOCA). The methodology is largely based on previously accepted methods for Mark II and Mark III containment designs with modifications to account for the differences in ABWR design.

Several improvements and corrections to the DCD were identified in [2] that may impact the suppression pool swell and related aspects of the hydrodynamic loads[1]. As a result of these identified changes, it is necessary to define new loading conditions that are applicable for the ABWR containment.

This report describes a methodology that uses the GOTHIC code to define post LOCA pool swell analysis for the ABWR containment design. **[**

] The drywell pressure transient is a specified boundary condition for the pool swell analysis. The drywell pressure transient was calculated using the methodology and mass and energy described in [9] with specific changes noted in Section 9. Only loads related to suppression pool swell during a LOCA are considered here. Application of pool swell results for structural loads analysis utilizes the previously accepted load methodology for the ABWR.

The GOTHIC modeling approach is compared against test data from the Pressure Suppression Test Facility [11] and compared with the DCD methodology and the DCD load parameters. The objective is to demonstrate that the described methodology gives pool swell results that bound experimental values and previously accepted values in the DCD.

[1] No corrections or improvements were identified for the condensation oscillation, chugging or SRV actuation related loads analyses.

3 Pool Swell Phenomena and Related Hydrodynamic Loads

The ABWR containment is shown in Figure 3-1. The drywell is split into upper and lower compartments. Vertical vents (regularly spaced at 36° intervals) run from the upper drywell down to the suppression pool. Each vertical vent is connected to the wetwell pool by three horizontal vents as shown in Figure 3-1. The lower drywell is connected to the vertical vent and there is no direct communication between the upper and lower drywell compartments.

In the event of a LOCA in the upper drywell, the upper and lower drywell compartments quickly pressurize and the water level in the vertical vent is depressed as the water is pushed into the wetwell. When the water level drops to the level of the horizontal vents, the steam/gas/drop mixture enters the wetwell. During this early phase of the event, the vent flow is primarily nitrogen from the drywell. A gas bubble or bubbles form in the wetwell and raise the pool surface. The pressure in the bubble depends on the pressures in the drywell and gas space above the pool, the hydrostatic head of water above the bubble and the inertia of the water that must be accelerated to make room for the bubble.

As the drywell pressure continues to rise, more gas is forced into the wetwell and the bubble continues to grow, forcing the pool surface higher. The bubble starts to rise relative to the rising water above the bubble due to buoyancy forces. The liquid slug above the bubble thins as some of the water above the bubble moves laterally and returns to the lower part of the pool.

As the liquid slug rises, the gas space volume is reduced and the gas space pressure increase opposes the lifting force and eventually decelerates the rising slug. As the slug slows the bubble continues to rise and breaks through the slug, forming a froth region that rises above the break through level.

Equipment that is located between the initial pool surface and the maximum slug height will be subjected to impact loads, followed by drag loads from the rising slug. In addition to the normal drag load from a steady velocity field, there will be an additional load due to the accelerating fluid moving past the equipment.

Equipment in the froth region will experience impact and drag loads although they will be lower than those in the slug regions because the mixture density of the froth is substantially lower.

After the bubbles have cleared the pool surface and the vent flow becomes predominately steam, the equipment in the slug and froth regions will be subjected to reverse drag loads as the water falls back to the pool. These loads will typically be substantially smaller than those due to the rising water because the fall back velocities are lower.

During the pool swell period, the pool walls, floor and ceiling will be subjected to increased loads due to the high bubble pressure, gas space pressure and the hydrostatic pressure.

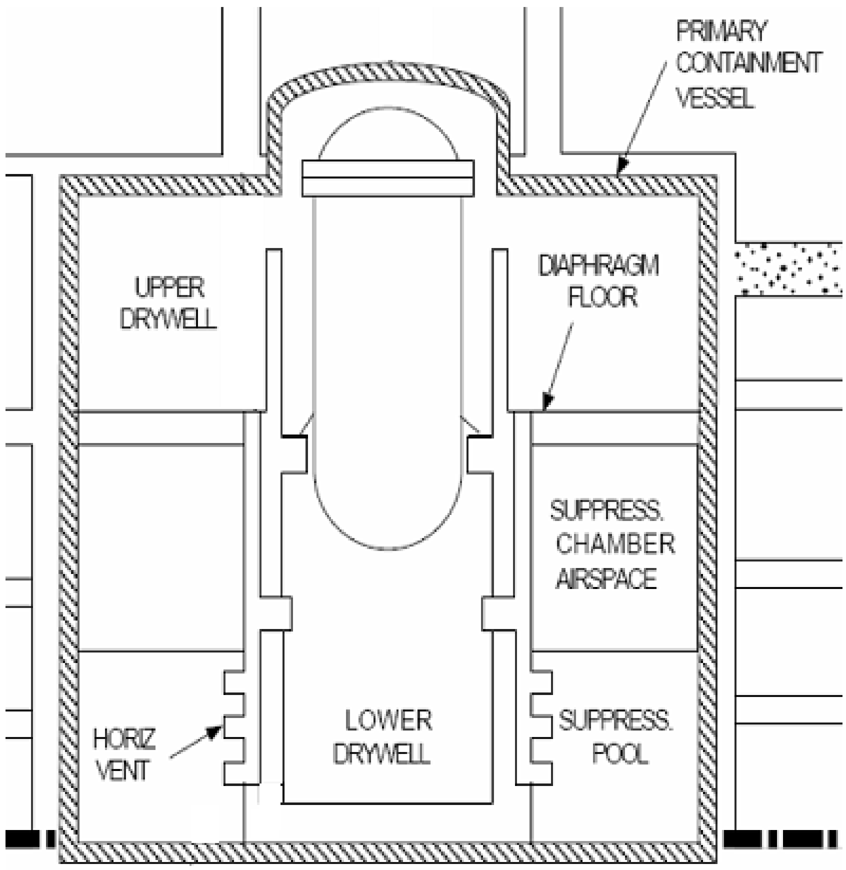

Figure 3-1 ABWR Primary Containment

4 GOTHIC Capabilities for Pool Swell Phenomena

GOTHIC solves the hydrodynamic equations for three separate phases: vapor (steam/gas mixture), liquid (water in continuous phase) and drops. A finite volume approach is used with the fluid pressure calculated at the cell center and the fluid velocities calculated at the cell faces. The momentum balance for each phase includes the fluid inertia, pressure gradient, body force, frictional drag from solid surfaces and interphase drag. The equation and constitutive models are described in detail in reference [4].

The behavior during the pool swell is controlled by fluid inertia, body forces (resulting in buoyancy), the interphase drag and the pressures in the bubble and gas space. There is also drag on the fluid from the wetwell walls and structures but these are ignored in the ABWR analysis to maximize the pool swell. As discussed in Section 5, the GOTHIC model for the bubble growth and pool swell is essentially one dimensional. It is recognized that the pool swell process involves multidimensional flow and that the one-dimensional modeling approach may not give realistic or best estimates of the pool swell phenomena. The one-dimensional model is constructed to provide bounding estimates for the maximum pool swell height and the swell velocity. In this context, the following describes how the multiphase, separated flow models in GOTHIC work within the one-dimension modeling approach and the GOTHIC modeling limitations to give a bounding estimate for the pool swell.

Figure 4-1 shows a control volume for the vapor phase momentum equation for the case of a collection of dispersed bubbles moving upward in a continuous liquid field. The indicated force terms include the pressures applied to the top and bottom of the volume, the momentum transport into and out of the volume, the body force due to gravity, and the interphase drag term. In the complete formulation there are additional force terms for the wall drag, viscous and turbulent shear and momentum transfer due to phase change that do not come into play in this analysis.

Figure 4-2 shows a similar momentum control volume for the liquid phase. The terms are the same except that the areas and volumes are defined by the liquid volume fraction (α_l) rather than the vapor volume fraction. The magnitude of the interphase drag force is the same as that for the vapor phase but in the opposite direction.

The momentum balance for the vapor and liquid phases gives

$$V\frac{\partial \alpha_v \rho_v u_v}{\partial t} \quad \sum F_v \tag{4.1}$$

$$V\frac{\partial \alpha_l \rho_l u_l}{\partial t} \quad \sum F_l \tag{4.2}$$

where F_v and F_l refer to the individual force terms shown in Figure 4-1 and Figure 4-2.

These equations are solved simultaneously together with the mass and energy balances for each phase to give the phase volume fractions, temperatures, densities and the fluid pressure.

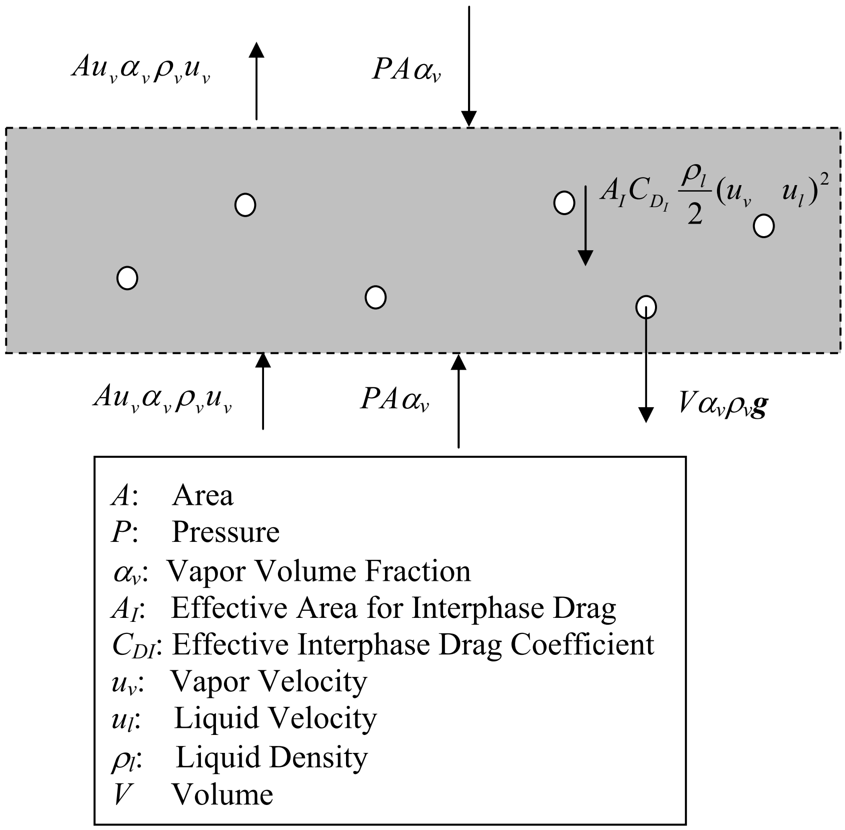

Figure 4-1 Vapor Phase Momentum Control Volume

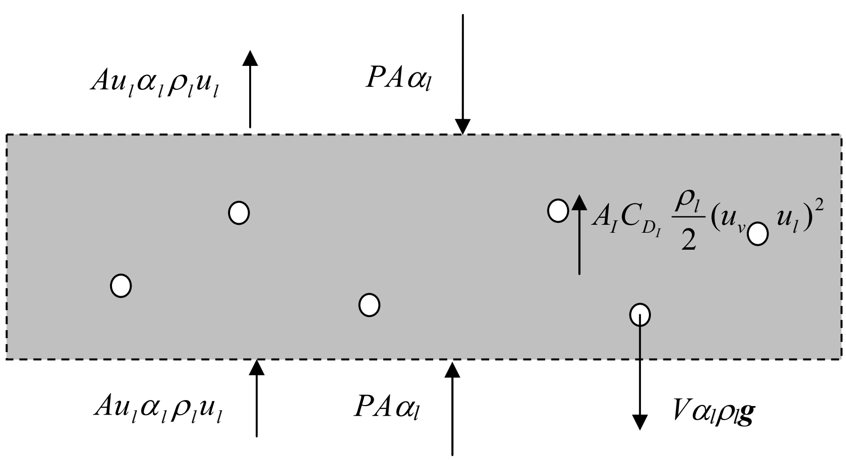

Figure 4-2 Liquid Phase Momentum Control Volume

The interphase drag is a controlling determinant in many multiphase applications. To determine the interphase drag, there must be some estimate of the local geometry of the phases. For this purpose, GOTHIC uses a simplified flow regime prescription that is based primarily on the vapor volume fraction in a cell and the surrounding cells. The possible flow regimes include a pool surface, small bubbly flow, mixed small and large bubbly flow, churn-turbulent flow, stratified horizontal flow and film flow.

GOTHIC first examines the vapor volume fraction in the cell and the surrounding cells to check for a pool surface. If the z-gradient of the vapor volume fraction is large, with vapor above and liquid below, such as in level 7 in Figure 4-3 then a pool surface is assumed. Otherwise, the logic proceeds to determine which of the other flow regimes is appropriate. If the vapor volume fraction is less than 0.2, then it is assumed that the vapor phase consists of a collection of small bubbles dispersed in the liquid phase. The diameter of the bubbles is given by a critical Weber number criterion of 10 using a relative velocity that is the smaller of the GOTHIC calculated phase velocities, the terminal velocity for distorted bubbles and 1.2 ft/s (0.37 m/s). As the vapor volume fraction increases above the 0.2 small bubble limit, the additional vapor is assumed to form larger bubbles. The assumed upper limit on the large bubble diameter is the smaller of 6 inches and twice the cell hydraulic diameter. The small/large bubble mixture regime is assumed for vapor volume fractions between 0.2 and 0.5 and the interphase drag coefficient is a weighted average of the separate drag coefficients for the small and large bubbles.

If the vapor volume fraction exceeds 0.8, a film flow geometry is assumed. For vapor fractions between 0.5 and 0.8 a churn-turbulent regime is assumed with large and small chunks of interspersed liquid and vapor. In this regime, the interphase drag is interpolated from the small/large bubble mixture drag and the film flow drag using the vapor phase volume fraction as the interpolating factor.

The details for the drag coefficients in each of these flow regimes are included in Section 8 of [4].

Conceptually, the bubble in the suppression pool may look something like that shown in Figure 4-3. A 1D grid is overlaid on the diagram. Consider first the top of the bubble that has just entered level 5. Here the actual flow regime is what might be called an inverted pool regime with vapor below a liquid surface. GOTHIC does not include an inverted pool regime in its regime map. In GOTHIC, the small amount of vapor in the cell would be assumed to exist as small bubbles. At the interface surface at the top of the bubble, the vertical velocity of the liquid and vapor phases are equal. In the GOTHIC separated two-phase model, this is equivalent to having a very large interphase drag coefficient. Moving upwards away from the surface, the liquid vertical velocity would decrease as some of the liquid moves laterally to the sides of the bubble. The effective drag coefficient over some region that encompasses the inverted pool surface would therefore be large, but small enough to allow some relative velocity between the vapor and liquid phases. The small bubble regime in GOTHIC has this same characteristic. The effective drag coefficient in this region allows a relative velocity of no more than 1.2 ft/s (0.37 m/s) under steady conditions. Consequently the water in the cell with the bubble surface is forced to move upward at a velocity that is slightly less the velocity of the expanding bubble surface.

Consider now the GOTHIC flow regime and interphase drag for cell 4. Here, the horizontal component of the bubble surface is predominately responsible for lifting the water while larger vertical phase slip is allowed on the vertical component of the interface. The GOTHIC flow regime map does not include this specific flow geometry but the interphase drag effects are similar to the small/large bubble regime where the combined effects of the small bubbles provide additional upward drag on the liquid phase while the reduced drag on the large bubbles (relative to the vapor volume) allows more slip between the liquid and vapor phases.

In level 3, GOTHIC would be approaching the film regime and the drag would be close to what would be expected on the vertical portion of the bubble.

In application to the 1D pool swell model described in Section 5, GOTHIC gives typical liquid phase volume fraction profiles in the wetwell like those shown in Figure 4-4. Here, the nitrogen is injected into the wetwell at about 3 m above the bottom of the pool. The resulting profiles at two times following the start of the LOCA event are shown. The profiles show the liquid slug that is lifted by the expanding bubble. The shape of the bubble is to some extent dictated by the imposed 1 dimensional model and may not be representative of the actual bubble. Nevertheless, the 1 dimensional model can be configured to give conservative estimates for the pool swell and swell velocity as shown in Appendix B. In the one-dimensional model for pool swell, the overall drag between the bubble and the water is over estimated as evidenced by the under prediction of the thinning of the rising slug above the pool (see Appendix B). This contributes to a conservative prediction of the pool swell and the swell velocity. A multidimensional model would allow for lateral movement in the liquid above the rising bubble and more realistic bubble modeling.

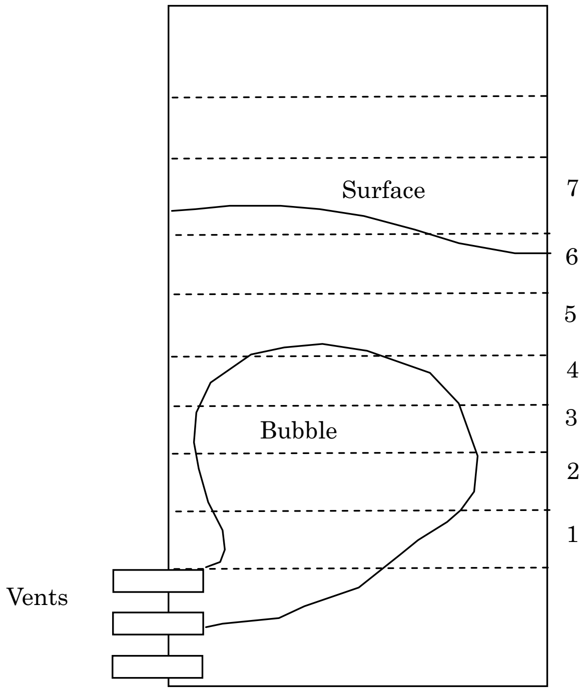

Figure 4-3 Conceptual Picture of Bubble Growth in an ABWR Suppression Pool

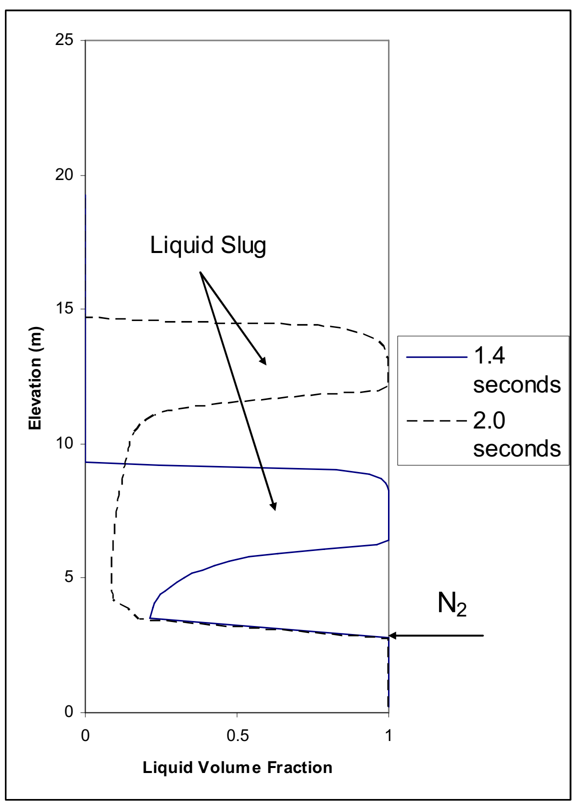

Figure 4-4 GOTHIC Predicted Vapor Phase Void Profile

Even though GOTHIC flow regime logic does not include flow geometries that are specific to a large expanding and rising bubble, the flow regime logic and associated drag models can reasonably simulate vent clearing, bubble growth and pool swell. GOTHIC gives good agreement for the vent clearing and pool swell in the Marviken tests as shown in Figure 4-5 and Figure 4-6. In these figures, the symbols are the measured data and the lines are from the GOTHIC simulation. A sequence of frames from an animation of the 3D simulation of the pool swell can be seen in Figure 4-7. The animation shows the vertical vent system and suppression pool in the Marviken containment following a pressure vessel blowdown in the connected drywell. The vents clear at about 1.5 seconds and the air bubble begins to grow. Between 2.4 and 2.6 seconds, the main air bubble detaches from the bottom of the vent pipes and starts to rise through the overlaying pool. This is about the time that the pool surface reaches its peak level and when the vent flow becomes predominantly steam. Although the Marviken geometry is similar to a Mark II BWR containment, the test demonstrates the fundamental capability of GOTHIC to model the dominant phenomena during pool swell in an ABWR. Further, GOTHIC has been validated for a wide range of related applications [5]. Inertia, momentum transport, drag effects and gas compression are validated with experimental data from the Battelle Model Containment, HDR, Marviken, the Edwards pipe blowdown tests and others.

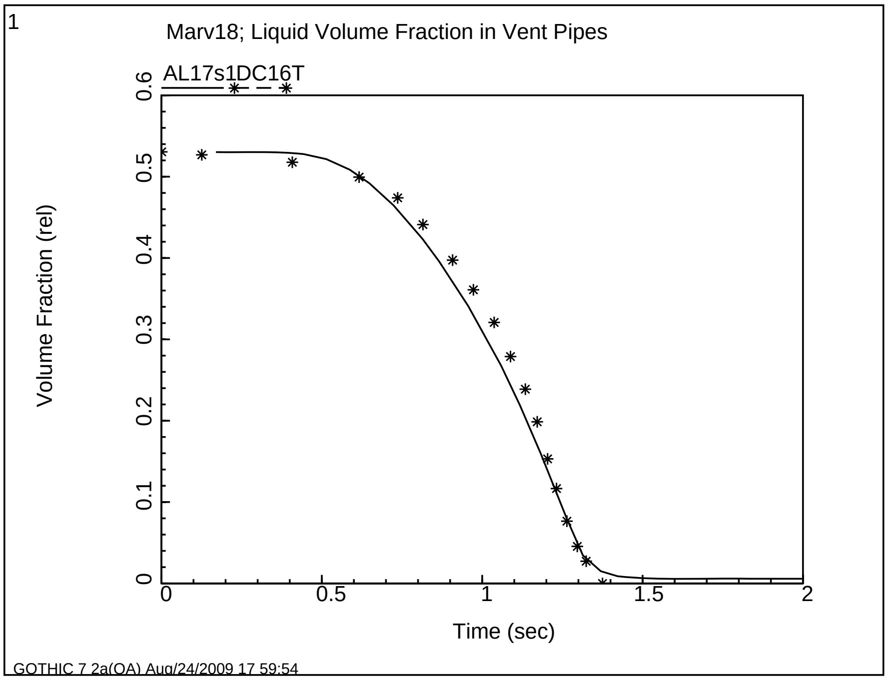

Figure 4-5 GOTHIC Predicted Vent Clearing for Marviken Test 18

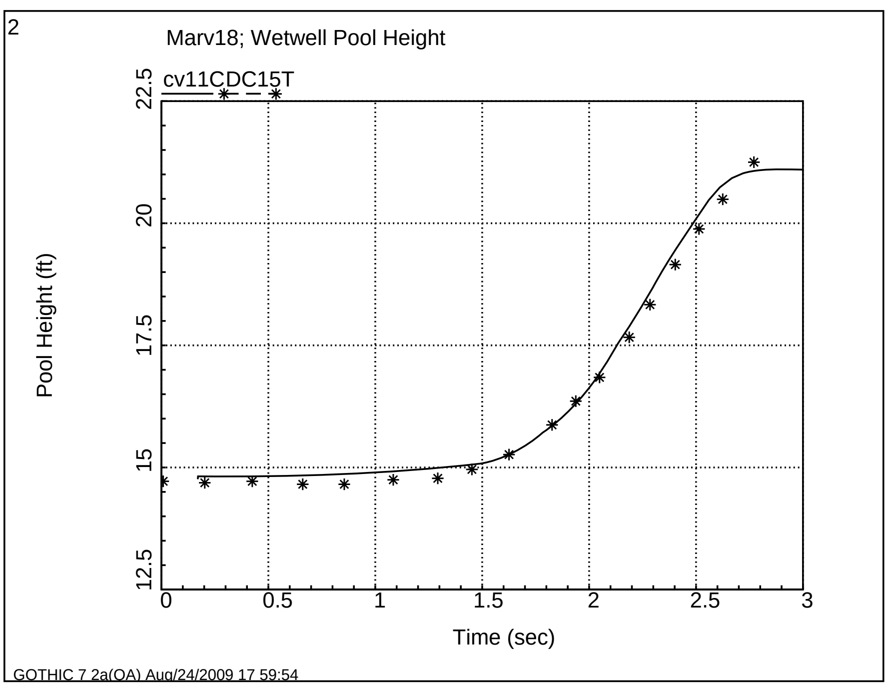

Figure 4-6 GOTHIC Predicted Pool Swell for Marviken Test 18

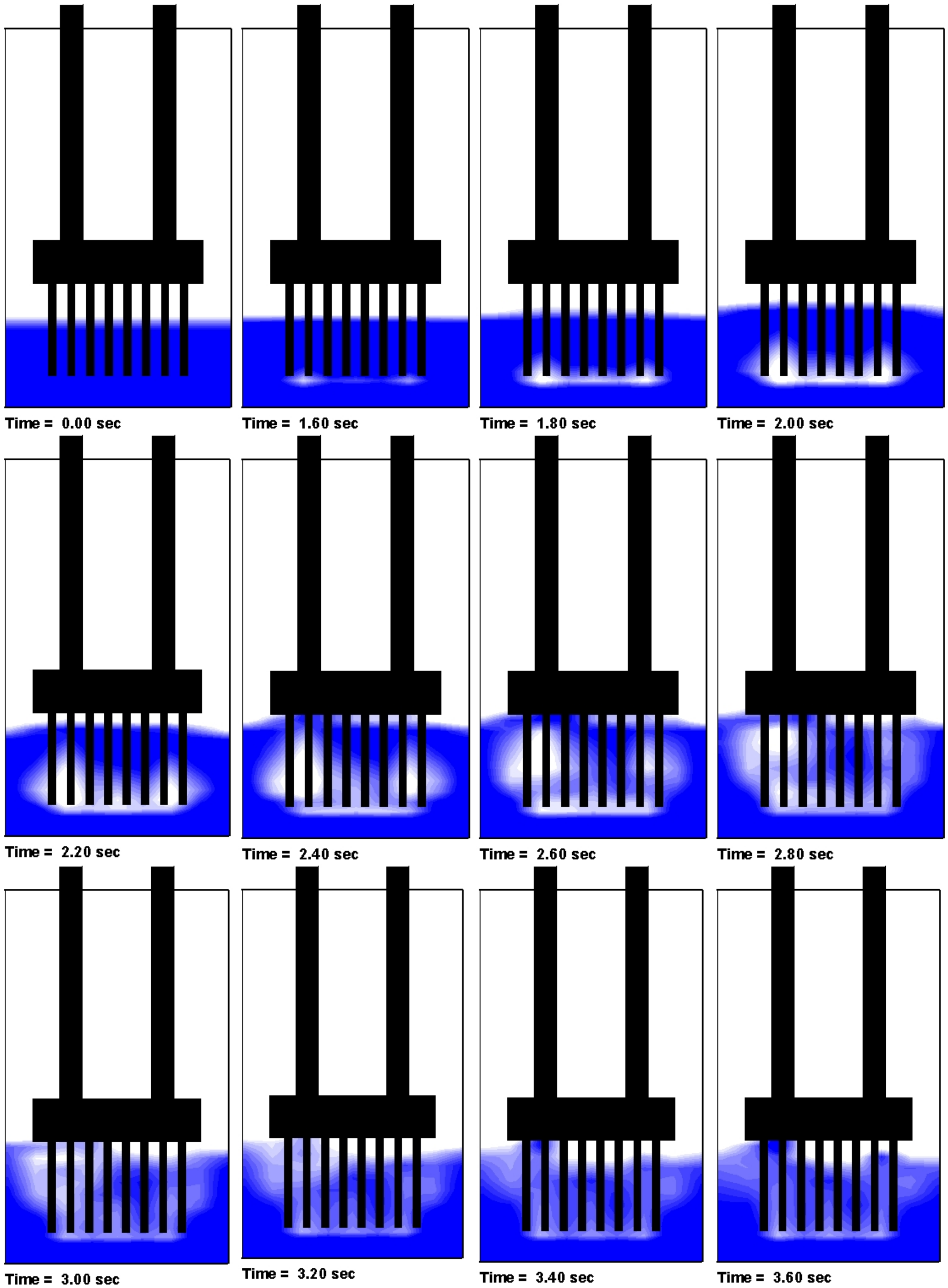

Figure 4-7 GOTHIC Simulation for Marviken Test 18 Pool Swell

5 GOTHIC Model Description for ABWR Pool Swell

The ABWR DCD identifies four parameters related to pool swell that are used to define hydrodynamic loads:

1. Maximum swell height
2. Maximum velocity of the rising water slug
3. Maximum bubble pressure during the pool swell phase
4. Maximum gas space pressure during the pool swell phase

A GOTHIC model for the ABWR pool swell was constructed that is intended to provide a conservative estimate of the pool load parameters listed above. The modeling approach is similar to the approach outlined in the DCD. **[**

] The drywell pressure transient is a specified boundary condition.

The overall noding diagram is shown in Figure 5-1. **[**

]

5.1 Model Specifics

The basic geometry input for the ABWR model is listed in Appendix A. The modeling specifics and assumptions are:

The predicted slug elevation versus time curve is constructed from GOTHIC output for the cell liquid volume fractions versus time. Points on the curve are determined by noting the time when the liquid volume fraction at a given level passes through 0.5. A post processing script is used for this purpose. The reported peak is the highest elevation attained while the slug is in its initial assent. Subsequent to this peak the water level may oscillate up and down over a narrow range while the bubble is breaking through the slug but the slug velocities are near zero during this phase.

The slug velocity is determined by analytically differentiating a polynomial least squares fit to the calculated top of slug elevation vs. time data set.

Maximum bubble and gas space pressures are defined as the pressures that occur at the first significant local maximum which occurs just before, or as, the bubble breaks through the pool surface.

Figure 5-1 Overall Noding Diagram

Figure 5-2 Wetwell Noding for 2D Model

6 Comparison of GOTHIC Methodology with the ABWR DCD Methodology

The GOTHIC ABWR modeling assumptions and methods are compared with those used for the DCD in Table 6-1.

Table 6-1 Comparison of DCD and GOTHIC Modeling Assumptions and Methods

	DCD		
Initial water in vertical and horizontal vent pipes	Ignored		
Vent location	Gas injected at elevation of top of top vent		
Vent area	Sequential addition of vents		
Injection Pressure	Drywell pressure transient		
Injection Composition	100% N_2 perfect gas		
Injection Temperature	Drywell from isentropic compression		
Vent Path Pressure Loss	Friction		
Vent Choking	Unclear		
Gas Temperature in Bubble	Drywell temperature		
Pool swell drag	Ignored		
Gas Temperature above Pool – Maximum Swell	Polytropic compression PV^n const (n 1.2)		
Gas Temperature above Pool – Maximum Pressure	Isentropic compression PV^n const (n 1.4)		
Pool swell region	80% of wetwell		
Rising water slug	Constant thickness		
Conservative multiplier on maximum swell velocity	1.1		

7 Comparison with Test Data

8 Comparison of GOTHIC Results with the ABWR DCD Results

The methodology described in Section 5 was used to construct a model for the case described in the DCD. The model geometry and initial condition input are the same as given in Appendix A. For this case the specified boundary condition pressure transient matches the results for the drywell pressure transient for the Feed Water Line Break (FWLB) in the DCD. For the DCD comparison, the temperature of the incoming nitrogen was assumed constant at 120°F (49°C). The results for the pool load parameters are shown in Table 8-1.

Except for the gas space pressure, the GOTHIC modeling approach gives more conservative estimates for the loading parameters than those listed in the DCD. The maximum gas space pressure is slightly lower than the value reported in the DCD. This may be due, in part, to the small amount of interphase heat transfer at the pool surface that is allowed in the GOTHIC model.

Table 8-1 Comparison of GOTHIC Methodology with the DCD Values

Parameter	DCD	GOTHIC Methodology
Max Swell Height (m)	7.0	7.4
Max Slug Velocity (m/s) with 1.1 multiplier	6.0	7.0
Max Gas Space Pressure (kPag)	108	106
Max Bubble Pressure (kPag)	133	141

9 Results for ABWR Design

The methodology described in Section 5 was used to construct a model for the ABWR containment design. Except for the drywell pressure transient, the model is the same as the one used for the DCD comparison in Section 8. **[**

] Appendix A provides the key input parameters for the model.

The results for the pool load parameters are summarized in Table 9-1.

These values are all substantially higher than those listed in the DCD. The GOTHIC models for full containment used to generate the drywell pressure transients include the corrections and improvements from NEDO-33372 as well as other Westinghouse specific design modifications resulting in higher drywell pressures compared to the DCD. Furthermore, as noted above, the limiting pressure transient during the pool swell phase comes from a MSLB case which was not considered in the DCD.

Figure 9-1 Drywell Pressure Transient for ABWR Pool Swell Design Analysis

Table 9-1 Suppression Pool Load Parameters of ABWR Design

Parameter	Design Case
Maximum Pool Swell Height (m)	8.8
Maximum Liquid Velocity (m/s)	10.9
Maximum Gas Space Pressure (kPag)	146
Maximum Bubble Pressure (kPag)	195

9.1 Pool Swell and Velocity

The elevation of the water slug surface versus time is shown in Figure 9-2. The swell level appears to rise above the reported peak value of 8.8 m above the initial pool level (15.8 m above pool bottom) after 2.5 seconds. This is when the initial slug is breaking up and the higher values are from the oscillating slug and the developing froth zone. These higher levels are ignored for maximum pool swell considerations.

The slug surface velocity versus time is shown in Figure 9-3. This curve was obtained by differentiating the polynomial fit for the slug elevation versus time. To obtain a good fit with a low order polynomial, the data set was limited to the dark portion of the curve shown in Figure 9-2. The peak velocity is reached at about 1.6 seconds, well before the slug gets to its maximum elevation at about 2.5 seconds. From the shape of the slug elevation versus time curve, it is apparent that the slug velocity is near zero when the bubble breaks through.

The slug velocity versus slug elevation is shown in Figure 9-4. The peak velocity is reached when the slug surface is about 11.6 m (38 ft) or 4.6 m above the initial pool surface elevation. However, for conservatism, this peak velocity is assumed to exist throughout the entire range of the pool swell.

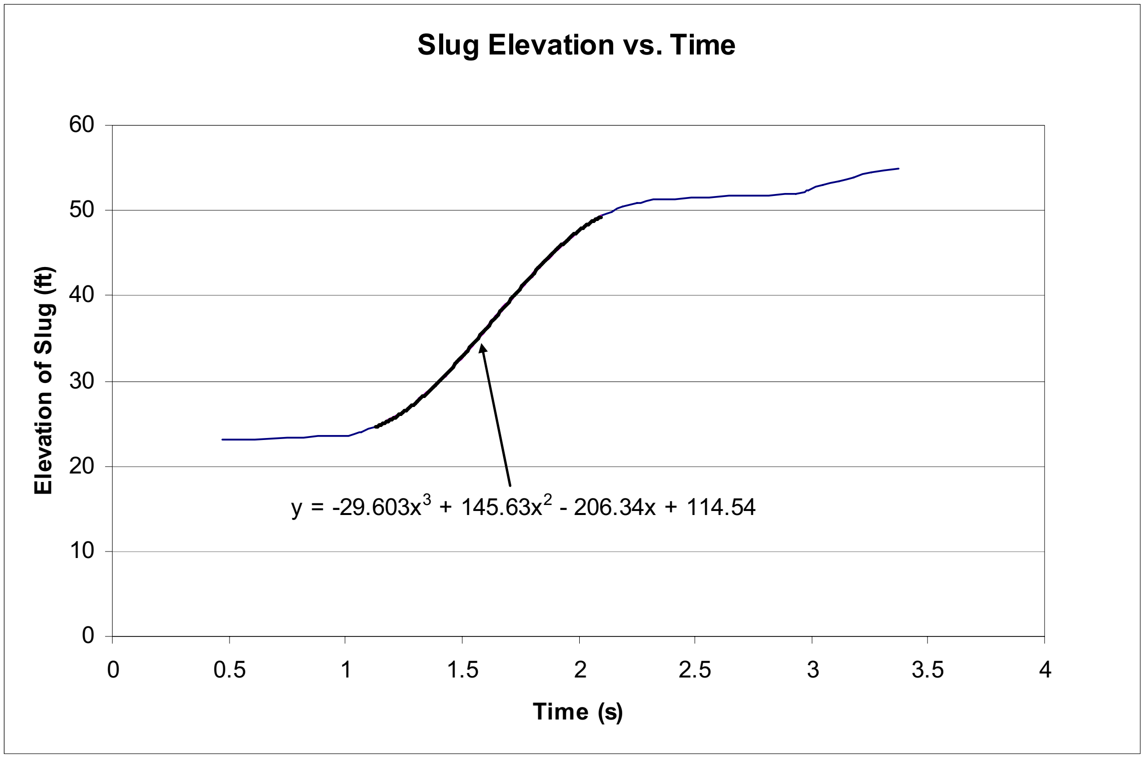

Figure 9-2 Slug Surface Elevation versus Time for the ABWR Design Loads

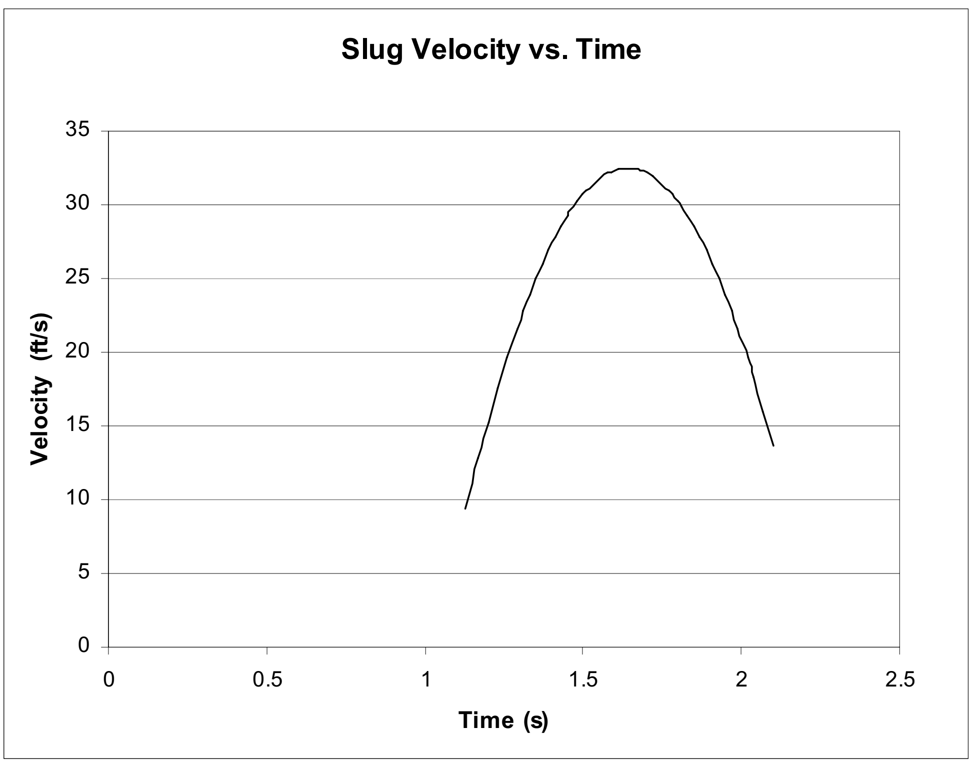

Figure 9-3 Slug Velocity versus Time for the ABWR Design Loads

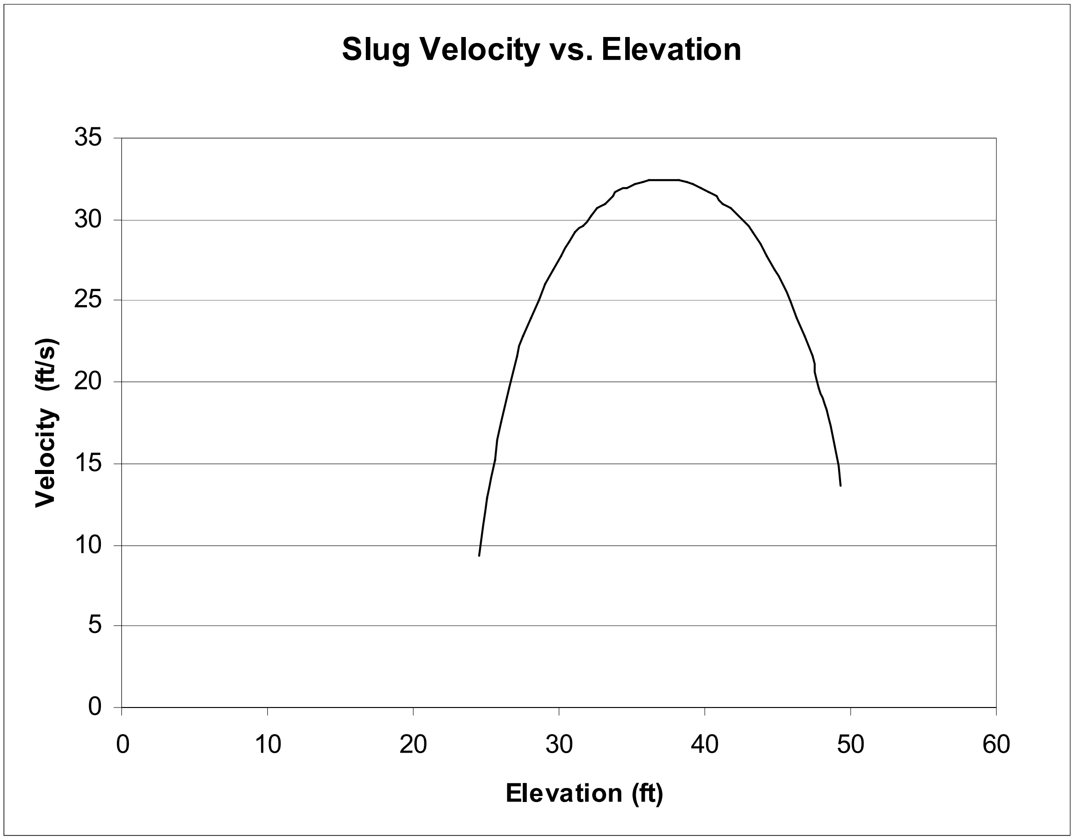

Figure 9-4 Slug Velocity versus Slug Surface Elevation for the ABWR Design Loads

9.2 Bubble and Gas Space Pressure

The bubble and gas space pressure are shown in Figure 9-5. The solid line is the gas space pressure, the dashed line is the bubble pressure and the dotted line is the specified drywell pressure. For the bubble pressure, the local peak just before the peak swell height is reached at 2.5 seconds is the reported maximum value. For gas space pressure, the local peak that occurs before the slug break up at 2.5 seconds is selected as the maximum gas space pressure. The bubble and gas space pressure continue to rise beyond these values, but these later values are beyond the end of the pool swell phase and are influenced by the assumption that only nitrogen is entering the wetwell. In an actual MSLB event, by 2.5 seconds a significant fraction of the vent flow will be steam which condenses in the pool.

Figure 9-5 also indicates the time period where the vent flow was choked. It can be seen that the first peak in the bubble pressure coincides with the establishment of choked flow in the vent. At this time the slug is near its peak velocity and the limited gas flow is not sufficient to maintain the pressure in the expanding bubble.

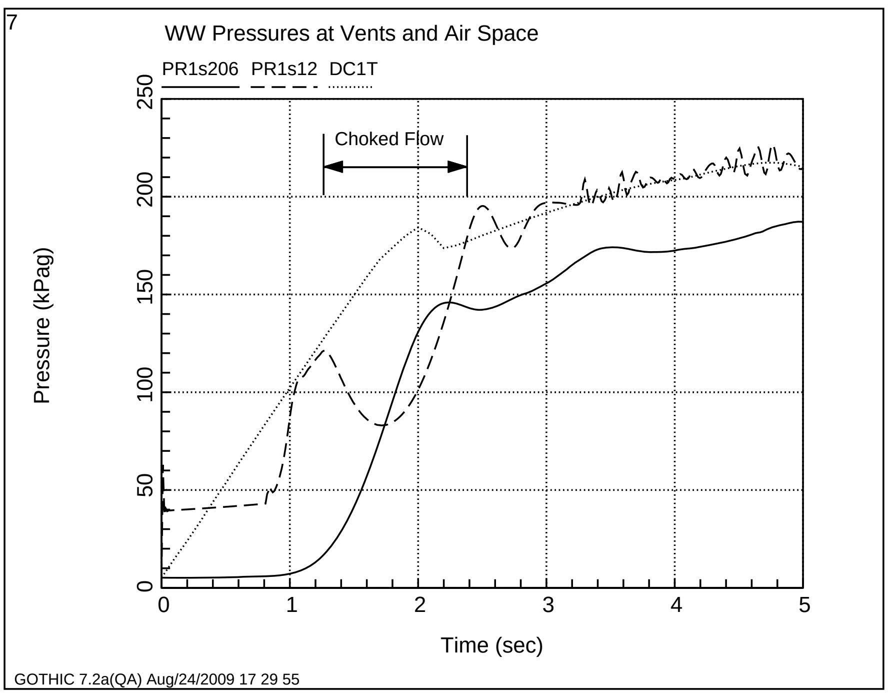

Figure 9-5 Bubble and Gas Space Pressure for ABWR Design Loads

9.3 Froth Height

The froth region is assumed to extend 3.3 meters above the maximum swell height. This value was based on PSTF test data and was accepted for the Mark III containment. It was also the assumed froth height in the ABWR DCD. This value is expected to be conservative for the ABWR design. In the Mark III containment, like the PSTF, the air space pressurization during the pool swell is small and the pool slug accelerates until the bubble breaks through. At that time the slug is at its maximum velocity and the momentum of the water will continue to carry some of it upward into the froth region. In contrast, in the ABWR, the water slug is essentially stopped by the high pressure in the gas space before break through. The bubble then rises through the still or falling water and breaks through. The water has no upward momentum to carry it into the froth region, and the froth is due only to the water that is carried up with the emerging gas bubbles. Further, compared to the Mark III containment and the PSTF tests, the higher gas space pressure in the ABWR will results in less vapor expansion as the bubbles break through the surface and consequently less liquid carry up.

10 Sensitivity Studies

The sensitivity of the pool swell and swell velocity to various GOTHIC input parameters and assumptions is discussed in Appendix E. The study shows that there is substantial conservatism in several of the modeling assumptions. **[**

] A smaller pool area factor would result in higher pool swell and swell velocity. However, the comparison against the PSTF test data indicates that the pool swell and swell velocity are bounded by the GOTHIC methodology without applying any adjustment factor (100% pool area factor) to account for 3D effects. Therefore the 80% factor is considered conservative. Based on this and the significant conservative margin in the other modeling parameters, the overall modeling approach is considered conservative.

11 Application of Pool Swell Results for Structural Loads Analysis

Once the pool swell results (i.e., gas space and bubble pressure, swell velocity and height) are obtained by GOTHIC analysis, the loads on structures in the wetwell are defined using the same methodology as described in the DCD. The methodology was originally developed and accepted for Mark II and Mark III containments, and it was also accepted for the ABWR. The detail descriptions are found in NUREGs [7, 8] and their references. A brief summary is provided in this section.

11.1 Structures in the Wetwell

Structures that will be subjected to pool swell loads due to LOCA events are:

- Personnel and equipment access tunnels (partially submerged)
- Grating
- Wetwell-to-drywell vacuum breakers
- SRV discharge piping above initial pool surface.

Submerged structures that will be subjected to pool swell induced loads are:

- Submerged portion of SRV discharge piping
- SRV discharge line X-quencher discharge device and its support structure
- ECCS suction lines and strainers.

Figure 11-1 shows typical arrangement of these structures.

11.2 Load Application

11.2.1 Pool Boundary Loads

During the pool swell phase of a LOCA, the wetwell region (the air space and the pool boundaries) is subjected to an internal dynamic pressure loading due to the expanding LOCA air bubble at the vent exits. The maximum wetwell air space pressure during pool swell is used in conjunction with the bubble pressure loading for structural evaluation of containment. The spatial distributions of the pressure loading conditions for use in structural evaluation are shown in Figure 11-2.

11.2.2 Impact Loads

As the pool level rises during pool swell, structures or components located above the initial pool surface (but lower than its maximum elevation) will be subjected to water impact and drag loads. The load calculation methodology will be based on that approved for Mark II and Mark III containments [7, 8].

The impact loading on structures between initial pool surface and the maximum swell height due to pool swell is calculated by the following equation:

$$P(t) = \frac{P_{Max}}{2}\left(1 - \cos\left(2\pi \frac{t}{T}\right)\right) \qquad (11.1)$$

where

P(t) is the pressure acting on the projected area of the structure

P_{Max} is the temporal maximum pressure acting on projected area of the structure

t is time

T is the duration of impact

Depending on the geometry of the equipment impacted by a water slug moving at velocity *V*(m/s), the pulse duration, *T*(s) is obtained from the following equations:

Long cylindrical target of diameter *D*(m)

$$T \quad 0.0463\frac{D}{V} \tag{11.2}$$

Long flat target of width *W*(m)

$$T \quad \begin{cases} 0.011\dfrac{W}{V} & for \quad V \geq 2.13\ m/s \\ 0.0052W & for \quad V < 2.13\ m/s \end{cases} \tag{11.3}$$

The maximum pressure obtained from

$$P_{Max} \quad 2\frac{I_p}{T} \tag{11.4}$$

I_p is the impulse is calculated using

$$I_p \quad \frac{M_H}{A}V \tag{11.5}$$

where M_H is the effective hydrodynamic mass obtained from the appropriate correlation described in [10].

A margin of 35% will be added to the impact pressure to obtain conservative design loads.

11.2.3 Drag Loads

Following the impact loading, the structure above the initial pool surface (but below the maximum swell height) will be subjected to the standard drag loading given by

$$P_d \quad \frac{1}{2}C_D\rho V^2 + V_A\rho\dot{V} \tag{11.6}$$

where

P_d is the drag pressure

C_D is standard drag coefficient

V is the pool swell velocity

ρ is the density of water

V_A is the acceleration drag volume

$\dot{V}$ is the pool acceleration

The standard drag coefficient, C_D and acceleration drag volume, V_A, used in the above equation are consistent with those defined and used in Reference 10. The velocity is 1.1 times the vertical velocity calculated from the pool swell analytical model.

11.2.4 Froth Load

Upon reaching the maximum pool swell height, the air bubbles that drive the water slug penetrates through the surface, resulting in bubble breakthrough leading to froth formation. This froth impacts structures located above the maximum bulk swell height. Structures located at elevations up to 3.3 m above the peak pool swell height are assumed to be subjected to froth impact loading. This froth swell height is the same as that defined for Mark III containment design. The load calculation methodology will be based on that approved for the Mark III containment [7].

11.2.5 Loads on Submerged Structure

After the vents are cleared of initially contained water and drywell air forced into the suppression pool, and a single bubble is formed around each vent exit. It is during the bubble growth period that unsteady fluid motion is created within the suppression pool. During this period, all submerged structures below the pool surface will be exposed to transient hydrodynamic loads. The load definition methodology for defining the LOCA bubble-induced loads on submerged structures will be consistent with the methodology used for prior plants, as described in [10].

Figure 11-1 Structures in the Wetwell

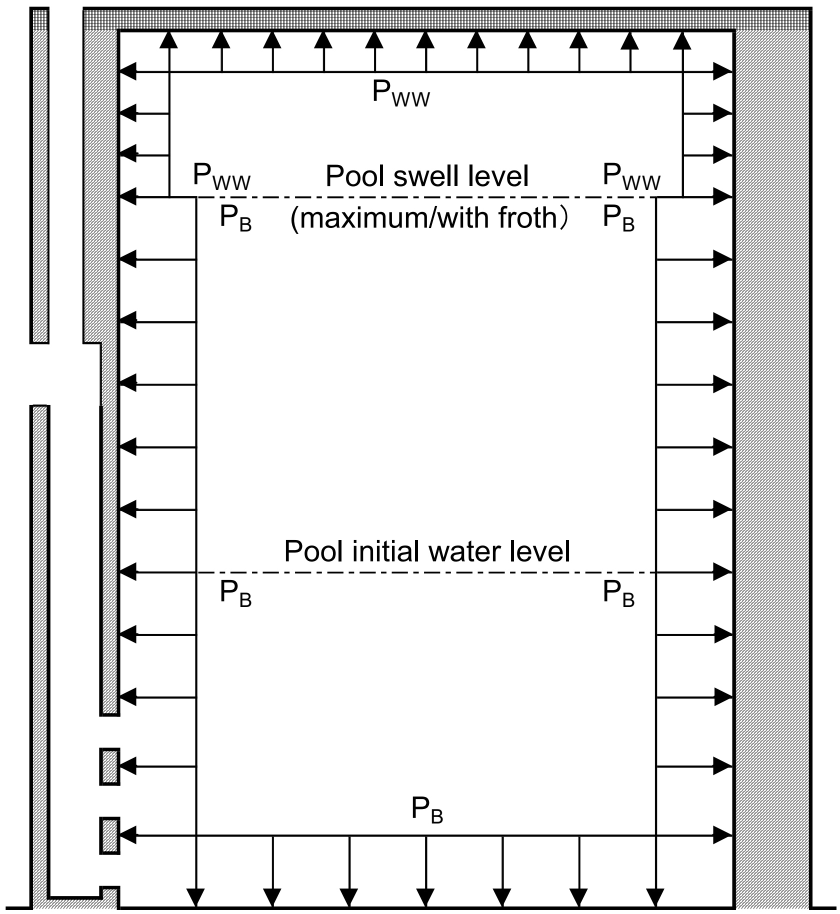

Figure 11-2 Pool Boundary Load Distribution

12 Conclusions

The described GOTHIC modeling approach for generating suppression pool hydrodynamic load parameters provides bounding values for the peak pool swell height, the peak swell velocity and peak bubble pressure compared to **[ ]** and compared to the approved DCD load parameters. The peak gas space pressure is slightly lower than the DCD value due to variations in the methodology.

The GOTHIC modeling approach includes several conservative assumptions:

The suppression pool load parameters calculated for the ABWR limiting design case account for the corrections and improvements identified in NEDO-33372 and are expected to conservatively bound the actual suppression pool behavior during a design basis accident.

13 References

1. NUREG-1503, "Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design," July 1994.
2. NEDO-33372, "Advanced Boiling Water Reactor (ABWR) Containment Analysis," September 2007.
3. NAI 8907-02, Rev. 17, "GOTHIC Containment Analysis Package User Manual," Version 7.2a(QA), January 2006.
4. NAI 8907-06, Rev. 16, "GOTHIC Containment Analysis Package Technical Manual," Version 7.2a(QA), January 2006
5. NAI 8907-09, Rev. 9, "GOTHIC Containment Analysis Package Qualification Report," Version 7.2a(QA), January 2006
6. NEDO-20533, "The General Electric Mark III Pressure Suppression Containment System Analytical Model," W. J. Bilanin, June 1974.
7. NUREG-0978, "Mark III LOCA-Related Hydrodynamic Load Definition," August 1984.
8. NUREG-0487, "MARK II Containment Lead Plant Program Load Evaluation and Acceptance Criteria," October, 1978.
9. WCAP-17058, "Implementation of ABWR DCD Methodology using GOTHIC for STP 3 and 4 Containment Design Analysis," R. Ofstun and T. George, June 2009.
10. NEDE-21471, "Analytical Model for Estimating Drag Forces on Rigid Submerged Structures Caused by LOCA and Safety Relief Valve Ramshead Air Discharges," F. J. Moody, September 1977.
11. Proceedings of the International Specialist Meeting on BWR-Pressure Suppression Containment Technology, Geesthacht, Germany, June 1-3, 1981.
12. ANL-77-47, "One-Dimensional Drift-Flux Model and Constitutive Equations for Relative Motion between Phases in Various Two-Phase Flow Regimes," M. Ishii, Argonne National Laboratory, October, 1977.

Appendix A - Key GOTHIC ABWR Suppression System Input Parameters

Table A-1 GOTHIC Input Parameters for ABWR Pool Swell

	English		Metric	
Wetwell				
Height	63.32	ft	19.30	m
Volume	338420	ft^3	9583	m^3
Width	73.11	ft	22.28	m
Depth	73.11	ft	22.28	m
Elevation	0.00	ft	0.00	m
Hydraulic Diameter	95.14	ft	29.00	m
Vertical Vent pipe				
Height	38.39	ft	11.70	m
Volume	4509.19	ft^3	127.69	m^3
Elevation	0.00	ft	0.00	m
Hydraulic Diameter	3.94	ft	1.20	m
Vertical vent to Dry Well				
Area	121.74	ft^2	37.11	m^2
Inertia Length	1.00	ft	0.30	m
Hydraulic Diameter	3.94	ft	1.20	m
Wet Well Initial Conditions				
Pressure	0.75	psig	5.25	kPag
Air Space Temperature	95	F	35	C
Water Temperature	95	F	35	C

Relative Humidity			100	%
Elevation of Top Pool Surface	22.97	ft	7.00	m

Dry Well Boundary Specification

Appendix B – Comparison of GOTHIC Pool Swell Methodology with Test Data

Appendix C – Drywell Pressure Transient for DCD Comparison

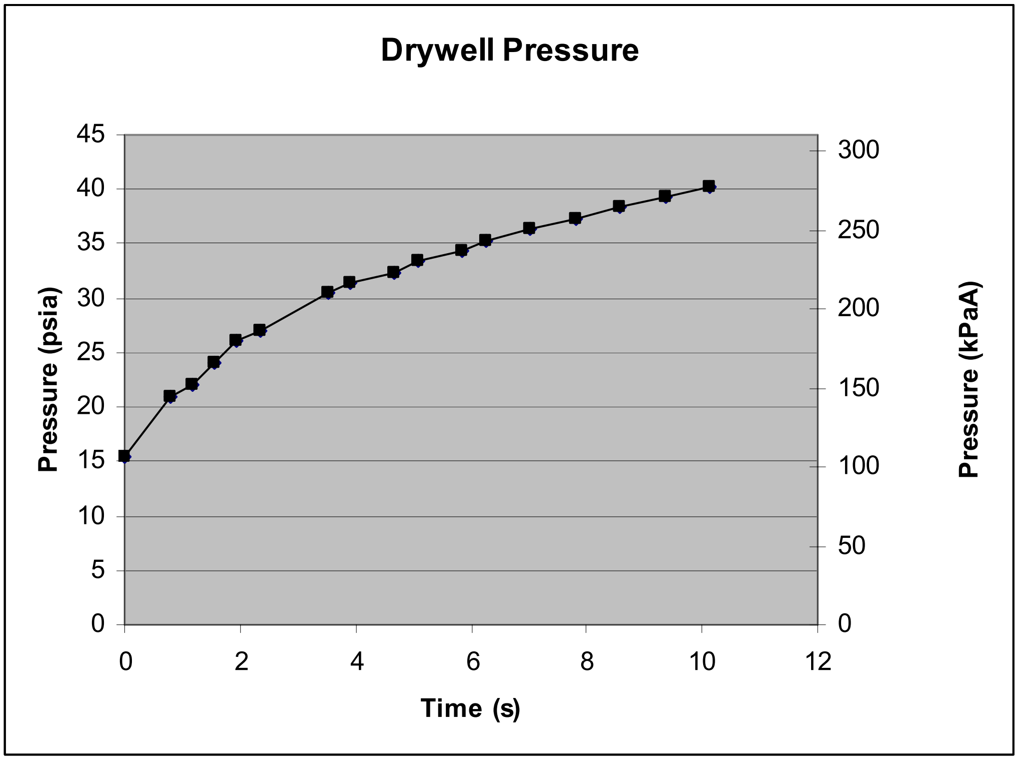

Figure C-1 Drywell Pressure for DCD FWLB

Appendix D – Drywell Pressure and Temperature Transients for Design Analysis

Appendix E – Sensitivity Studies

E.1 Sensitivity Studies

Additional cases based on the ABWR design case were run to investigate the sensitivity of the pool swell and swell velocity to some of the GOTHIC input parameters. The graphs for the pool swell velocity shown below do not include the **[ ]** conservatism multiplier.

E.2 Vent Loss Factor

Figures E-1 and E-2 show the pool swell and swell velocity for 3 values of the horizontal vent loss factor. **[**

]

E.3 Pool Area Factor

Figures E-3 and E-4 show the pool swell and swell velocity for 3 values of the assumed pool area factor. **[**

]

E.4 Vent Inertia Length

E.5 Gas Space Temperature

E.6 Vent Location