Westinghouse Non-Proprietary Class 3

WCAP-16606-NP-A
Revision 0

January 2008

Supplement 2 to BISON Topical Report RPA 90-90-P-A

Westinghouse

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WCAP-16606-NP-A
Revision 0

Supplement 2 to BISON Topical Report RPA 90-90-P-A

Original Version: August 2006
Approved Version: January 2007

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***Electronically Approved Records Are Authenticated in the Electronic Document Management System**

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Section A

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

October 22, 2007

Mr. James A. Gresham, Manager
Regulatory Compliance and Plant Licensing
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: FINAL SAFETY EVALUATION FOR WESTINGHOUSE ELECTRIC COMPANY (WESTINGHOUSE) TOPICAL REPORT (TR) WCAP-16606, REVISION 0, "SUPPLEMENT 2 TO BISON TOPICAL REPORT RPA 90-90-P" (TAC NO. MD2952)

Dear Mr. Gresham:

By letter dated August 15, 2006, Westinghouse submitted Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P," to the U.S. Nuclear Regulatory Commission (NRC) staff. By letter dated September 5, 2007, an NRC draft safety evaluation (SE) regarding our approval of TR WCAP-16606-P, Revision 0, was provided for your review and comments. By letter dated September 13, 2007, Westinghouse commented on the draft SE. The NRC staff's disposition of Westinghouse's comments on the draft SE are discussed in the attachment to the final SE enclosed with this letter.

The NRC staff has found that TR WCAP-16606-P, Revision 0, is acceptable for referencing in licensing applications for Westinghouse-designed pressurized water reactors to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

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

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

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

If you have any questions, please contact Jon H. Thompson at (301) 415-1119.

Sincerely,

Ho K. Nieh, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Final SE

cc w/encl:
Mr. Gordon Bischoff, Manager
Owners Group Program Management Office
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

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

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT (TR) WCAP-16606, REVISION 0,

"SUPPLEMENT 2 TO BISON TOPICAL REPORT RPA 90-90-P"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION AND BACKGROUND

By letter dated August 15, 2006, Westinghouse Electric Company (Westinghouse) submitted TR WCAP-16606-P, Revision 0 (Reference 1), "Supplement 2 to BISON Topical Report RPA 90-90-P" (Supplement 2), which supplemented the BISON code to extend its capability to calculate the mass and energy releases to containment during an anticipated transient without scram (ATWS). No changes to the ATWS methodology were proposed. The containment response methodology is addressed in a separate TR.

The main purpose of Supplement 2 is to extend the applicability of the BISON code to the analysis of ATWS sequences beyond the time of the peak pressure to determine whether the mass and energy release to the containment during the boron injection phase of the accidents is acceptable.

Supplement 2 also proposed to extend the AA78 slip/void correlation to higher pressures. A similar proposal was previously submitted to the NRC staff as a license amendment request by letter dated June 15, 2005, by Exelon Generating Company, LLC (Exelon) (Reference 2). The U.S. Nuclear Regulatory Commission (NRC) staff approved this request by letter dated April 4, 2006 (Reference 3). The same material contained in Reference 2 was included in the TR WCAP-16606-P, Revision 0, so that it could be approved for generic application to all boiling water reactor plants.

The AA78 correlation was approved by the NRC staff in a letter dated October 24, 1989 (Reference 4). While the BISON description report was originally identified as TR WCAP-11236, it is also, and more commonly, identified as ABB Combustion Engineering Nuclear Operations TR RPA 90-90-P-A (Reference 5). Supplement 1 is identified as TR CENPD-292-P-A (Reference 6), and was approved for use by the NRC staff by letter dated October 16, 1995 (Reference 7). Supplement 2 is the subject of this safety evaluation (SE).

Westinghouse responded to a request for additional information by the NRC staff regarding Supplement 2 in letters dated May 14 and July 26, 2007 (References 8 and 12).

2.0 REGULATORY EVALUATION

Section 50.62 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Requirements for reduction of risk from anticipated transients without scram (ATWS) events for light-water-cooled nuclear power plants," was considered during this review.

Standard Review Plan (SRP) Chapter 15, Section 8 (SRP 15.8), "Anticipated Transients Without Scram," was also considered during this review. Specifically, SRP 15.8 was used to examine this TR with respect to Appendix A of 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC)-38, as it relates to ensuring that the containment pressure and temperature are maintained at acceptably low levels following any accident that deposits reactor coolant in the containment, and GDC-50, as it relates to ensuring that the containment does not exceed the design leakage rate when subjected to the calculated pressure and temperature conditions resulting from any accident that deposits reactor coolant in the containment.

3.0 TECHNICAL EVALUATION

3.1 The Boron Injection Model

The boron concentration model calculates the boron concentration in the reactor vessel based on:

- a boron solution insertion flow rate,
- a boron mass fraction,
- total boron solution mass,
- a methodology penalty factor, and
- a core simulator correction factor to account for actual core contents and three-dimensional effects in the boron reactivity worth.

To obtain the concentration of boron in the reactor pressure vessel, Westinghouse assumes a conservative model denoted as the "perfect mixing" model. In this model the total core water volume is used to derive the concentration based on the total water mass in the reactor vessel, (Reference 1).

The BISON "perfect mixing" model generates a conservative boron concentration in the core. Details of the calculational method of the boron concentration model in BISON are provided in Section 4.1.2 of Reference 1.

The NRC staff requested additional information regarding the boron model concentration assumptions. Specifically, the NRC staff requested additional information regarding the boron settling model after injection, concentration levels, and time dependent projection of the SLCS function as a function of time. Westinghouse supplemented its response to the NRC staff by letters dated May 14, 2007 (Reference 8), and July 26, 2007 (Reference 12) and these addressed the NRC staff concerns regarding the boron model concentration assumptions.

3.2 The Neutron Kinetics Model

The neutron kinetics model provided in the BISON code is described in detail in Section 4 of Reference 1. The basis model was not changed for this submittal with respect to the basic analytical formulation and nuclear cross-section models. A brief description of the neutronic model in BISON is provided in the next section.

3.2.1 The Basic Model

The neutron kinetics model used in BISON is a time-dependent two-group diffusion model with one-dimensional (axial) space dependence. The neutron kinetics properties of the reactor core are calculated from local cross-sections and delayed neutron data. Boron in the core and bypass can be accounted for using a correction to the nuclear cross-sections derived according to the models and the methodology provided in Appendix A of Reference 5.

Prior to a transient calculation, a steady state is initialized by iterations between the neutron kinetics model and the thermal-hydraulics model until the power distribution and the void and temperature distributions correspond to each other. Nuclear cross-sections are provided as polynomial functions.

The Doppler correction includes the fuel temperature influence on k from all cross-sections represented in the model. These corrections are calculated by the interface program off-line. A complete set of polynomials are thus provided, accounting for fuel with no control rods present, and another set of polynomials with control rods fully inserted for each fuel type.

3.2.2 Accounting for Boron in Cross-Section Calculations

The inclusion of a boron model into the BISON code necessitated changes to the neutron kinetics model implemented in an earlier version of BISON.

The boron reactivity impact in BISON is assumed to be independent of the fuel or core as long as the ppm value is calculated properly. Modeling of the boron reactivity impact is documented in Reference 11.

To determine the impact of boron reactivity, the BISON model utilizes a separate set of nuclear cross-sections with different boron concentrations. The separate set of nuclear cross-sections is used in each axial core model cell generating nuclear cross-sections for zero boron and for the actual boron concentration in the model. This set of cross-sections is evaluated both with and without control rods.

The cross-section model consists of a set of tables with independent variations at each individual burnup, density parameters, coolant temperature, and boron concentration. These cross-sections are, like the base set of cross-sections, calculated with a two-dimensional lattice code at different burnups, varying core and bypass densities to generate dependencies of void and temperature in the core/bundle, and bypass in all combinations for the same voids. At all these combinations, the boron concentration is also varied.

Boron reactivity impact is only an impact from the water densities in the different parts of the core, since the boron is dissolved in the water. The more water is present, the more boron there

is at a given concentration of boron in ppm. This impact varies between different fuel designs, different core loadings, and different operating points. Thus, the BISON boron model necessitates that a normalization of the boron reactivity worth is performed versus a three-dimensional core simulator (POLCA7) code, thus, ensuring boron reactivity accountability in the model.

3.3 Extension to the AA78 Slip/Void Correlation

The NRC staff imposed a limitation on the use of the AA78 correlation above 10 MPa when BISON was originally accepted in 1989 (Reference 4). This was identified as Condition 4 in the NRC staff SE for TR RPA 90-90-P-A (Reference 4).

Exelon provided justification for the use of the AA78 correlation above 10 MPa in its license amendment request for the transition to Westinghouse fuel at the Dresden Nuclear Power Station, Units 2 and 3, and the Quad Cities Nuclear Power Station, Units 1 and 2 (Reference 2).

To demonstrate the applicability of the AA78 slip correlation, in combination with the Electric Power Research Institute (EPRI) boiling model (Reference 9), at pressures above 10 MPa, Exelon provided a comparison of these models extended to higher pressures and higher steam qualities than originally used to justify the AA78 correlation in TR RPA 90-90-P-A. The EPRI slip/boiling correlation has been verified for a wide range of pressures, and was developed to fit not only the rod bundle data which formed the basis of the AA78 correlation, but also other data including measurements in rectangular tubes. This comparison showed the AA78 void correlation does not have any discontinuity or threshold effect for pressures up to maximum value proposed in this request. The NRC staff approved the extended pressure range in 2006 in license amendments for the above mentioned Exelon plants (Reference 10).

High steam qualities are only expected to occur during pressure decrease transients. Experience indicates that pressurization transients, such as ATWS, do not lead to high qualities, especially if the transient is fast. Safety and relief valves would rapidly control the reactor pressure below nine MPa and in the verified AA78 correlation range. The upper limit on the steam quality for a steam dome pressure above nine MPa covers the expected conditions during a pressurization transient without scram. Additionally, for all foreseen ATWS applications, the ASME 120 percent maximum design pressure limit is below 10.5 MPa. Therefore, the NRC staff finds that there is reasonable assurance that the AA78 correlation will be used within the proposed limits for the expected range of applications, including ATWS.

4.0 LIMITATIONS AND CONDITIONS

4.1 AA78 Slip/Void Correlation

For reactor dome pressures less than 10 MPa, there are no limitations on the use of the AA78 correlation, as this correlation has been approved by the NRC staff previously. For pressures higher than 10 MPa during an ATWS event, if the quality exceeds the upper limit identified in TR WCAP-16606-P, Revision 0, then use of the TR is not approved.

5.0 CONCLUSION

The NRC staff concludes the inclusion of the boron model to the BISON code is acceptable for use by boiling water reactors. The boron injection model as described in TR WCAP-16606-P, Revision 0 (Reference 1), can be used to extend the applicability of the code to the analysis of ATWS sequences beyond the time of the peak pressure and to determine the mass and energy release to the containment during the boron injection phase of the accidents (Reference 12).

The NRC staff concludes that there is reasonable assurance that the AA78 correlation will be used within the proposed limits, subject to the limitation identified in Section 4.1 above, for the expected range of applications, including ATWS.

6.0 REFERENCES

1. J. A. Gresham, Westinghouse Electric Company, letter to the U.S. Nuclear Regulatory Commission,"Submittal of WCAP-16606-P/WCAP-16606-NP, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (Proprietary/Non-Proprietary)," August 15, 2006, LTR-NRC-06-48 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML062360486).

2. P. R. Simpson, Exelon Generation Company, LLC, letter to the U.S. Nuclear Regulatory Commission, "Request for License Amendment Regarding Transition to Westinghouse Fuel," June 15, 2005, RS-05-078 (ADAMS Accession No. ML060620352).

3. M. Banerjee, U.S. Nuclear Regulatory Commission, letter to C. M. Crane, Exelon Generating Company, LLC, April 4, 2006 (ADAMS Accession No. ML060750258).

4. A. C. Thadani, U.S. Nuclear Regulatory Commission, letter to W. J. Johnson, Westinghouse Electric Corporation, "Acceptance for Referencing of Licensing Topical Report WCAP-11236 Regarding the Westinghouse Boiling-Water Reactor Transient Analysis Code BISON," October 24, 1989 (ADAMS Legacy Library Accession No. 8911010136).

5. ABB Combustion Engineering Nuclear Operations, "BISON - A One Dimensional Dynamic Analysis Code for Boiling Water Reactors," RPA 90-90-P-A, Revision 0, December 1991.

6. ABB Combustion Engineering Nuclear Operations,"BISON - A One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," CENPD-292-P-A, July 1996.

7. R. C. Jones, U.S. Nuclear Regulatory Commission, letter to D. Ebeling-Koning, ABB CENO Fuel Operations, "CENPD-292-P, "BISON - One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification (TAC NO. M90165)," October 16, 1995 (ADAMS Legacy Library Accession No. 9510230138).

8. B. F. Maurer, Westinghouse Electric Company, letter to U.S. Nuclear Regulatory Commission, "Response to NRC's Request for Additional Information by the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP- 16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2925) (Proprietary/Non-proprietary)," May 14, 2007, LTR-NRC-07-15 (ADAMS Accession No. ML071440450).

9. Electric Power Research Institute (G. S. Lellouche, B. A. Zolotar), "A Mechanistic Model for Predicting Two-Phase Void Fraction for Water in Vertical Tubes, Channels, and Rod Bundles," EPRI NP-2246-SR, 1982.

10. M. Banerjee, U.S. Nuclear Regulatory Commission, letter to C. M. Crane, Exelon Generation Company, LLC, "Dresden Nuclear Power Station, Units 2 and 3, and Quad Cities Nuclear Power Station, Units 1 and 2 - Issuance of Amendments Re: Transition to Westinghouse Fuel and Minimum Critical Power Ratio Safety Limits (TAC No. MC7323, MC7324, MC7325 and MC7326," April 4, 2006 (ADAMS Accession No. ML060750258).

11. ABB Combustion Engineering, "The Advanced PHOENIX and POLCA Codes for Nuclear Design of Boiling Water Reactors," CENPD-390-P-A, December 2000.

12. J. A. Gresham, Westinghouse Electric Company, letter to U.S. Nuclear Regulatory Commission, "Clarification Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2952) (Proprietary/Non-proprietary)," July 26, 2007, LTR-NRC-07-34 (ADAMS Accession No. ML072270094).

Attachment: Resolution of Comments

Principal Contributors: A. Attard
E. Throm

Date: October 22, 2007

RESOLUTION OF WESTINGHOUSE ELECTRIC COMPANY (WESTINGHOUSE)

COMMENTS ON DRAFT SAFETY EVALUATION FOR TOPICAL REPORT (TR)

WCAP-16606, REVISION 0, "SUPPLEMENT 2 TO BISON TOPICAL REPORT RPA 90-90-P"

(TAC NO. MD2952)

By letter dated September 13, 2007, Westinghouse provided five comments on the draft safety evaluation (SE) for TR WCAP-16606-P-A, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P." Some information in the draft SE for this TR was identified as proprietary; therefore, the draft of this SE will not be made publicly available. The following are the NRC staff's resolution of these comments:

Draft SE comments for TR WCAP-16606, Revision 0:

1. Proprietary Statement – Recommendation: Suggest either bracketing the following: [proprietary statement deleted] or delete the sentence (Page 1, Line 15).

   NRC Resolution for Comment 1 on Draft SE:

   The sentence will be changed to read: "Supplement 2 also proposed to extend the AA78 slip/void correlation to higher pressures."

2. Proprietary Statement - Recommendation: Suggest either bracketing the following: [proprietary statement deleted] or delete the sentence (Page 2, Lines 36-42).

   NRC Resolution for Comment 2 on Draft SE:

   The paragraph will be changed to read: "The BISON "perfect mixing" model generates a conservative boron concentration in the core. Details of the calculational method of the boron concentration model in BISON are provided in Section 4.1.2 of Reference 1."

3. Proprietary Statement – Recommendation: Suggest either bracketing the following: [proprietary statement deleted] or delete the sentence (Page 3, Line 3[5]-3[6]).

   NRC Resolution for Comment 3 on Draft SE:

   The sentence will be changed to read: "Modeling of the boron reactivity impact is documented in Reference 11."

4. Proprietary Statement – Recommendation: Suggest either bracketing the following: [proprietary statement deleted] or delete the sentence (Page 4, Line [1-7]).

   NRC Resolution for Comment 4 on Draft SE:

   The paragraph will be deleted.

ATTACHMENT

5. Proprietary Statement - Recommendation: Suggest either bracketing the following: [proprietary statement deleted] or delete the sentence (Page 4, Line [9-11]).

   NRC Resolution for Comment 5 on Draft SE:

   The sentence will be deleted.

Section B

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Westinghouse

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Nuclear Services
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U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Direct tel: 412/374-4643
Direct fax: 412/374-4011
e-mail: greshaja@westinghouse.com

Our ref: LTR-NRC-06-48

August 15, 2006

Subject: Submittal of WCAP-16606-P / WCAP-16606-NP, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (Proprietary/Non-Proprietary)

Enclosed are 5 Proprietary and 3 Non-Proprietary copies of WCAP-16606-P / WCAP-16606-NP, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" submitted to the NRC for Review and Approval. It is requested that the above topical be approved by August 2008. It is also requested that the NRC provide an estimate on the man-power resources required for the review and a tentative date for an acceptance meeting.

WCAP-16606-P / WCAP-16606-NP are the second supplement to RPA 90-90-P-A and address the following BISON features:

- Extend the capability of the BISON code for calculation of mass and energy release to the containment during Anticipated Transient without Scam (ATWS). There are no changes to the ATWS methodology. The containment methodology is being addressed via a different topical submittal.
- Model the reactivity impact from Boron injection during an ATWS transient.
- Extend the AA78 slip/void correlation for pressures up to 12 MPa. This modification was already submitted and approved by the NRC in the Exelon Licensing Agreement Request, used by RS-05-78, dated June 15, 2005. It is included in this submittal so that it can be approved for application for all BWR plants.

Also enclosed are:

1. One (1) copy of the Application for Withholding, AW-06-2186 with Proprietary Information Notice and Copyright Notice.
2. One (1) copy of Affidavit, AW-06-2186.

This submittal contains Westinghouse proprietary information of trade secrets, commercial or financial information which we consider privileged or confidential pursuant to 10 CFR Section 2.390. Therefore, it is requested that the Westinghouse proprietary information attached hereto be handled on a confidential basis and be withheld from public disclosure.

Correspondence with respect to any Application for Withholding should reference AW-06-2186 and should be addressed to J. A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Enclosures

cc: G. V. Cranston, NRR
A. C. Attard, NRR
G. S Shukla, NRR
S. E. Peters, NRR

Westinghouse

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e-mail: greshaja@westinghouse.com

Our ref: AW-06-2186

August 15, 2006

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Submittal of WCAP-16606-P, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (Proprietary)

Reference: Letter from J. A. Gresham to Document Control Desk, LTR-NRC-06-48, dated August 15, 2006

The Application for Withholding is submitted by Westinghouse Electric Company LLC (Westinghouse) pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-06-2186 accompanies this application for withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

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

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-06-2186 and should be addressed to J. A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

AW-06-2186

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared J. A. Gresham, 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:

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed
before me this 15th day
of August, 2006

Sharon L. Fiori
Notary Public

Notarial Seal
Sharon L. Fiori, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires January 29, 2007
Member, Pennsylvania Association Of Notaries

(1) I am Manager, Regulatory Compliance and Plant 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 rulemaking 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 which 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.

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

(a) Extend the capability of BISON code for calculation of mass and energy release to the containment during Anticipated Transient with SCRAM (ATWS).

(b) Model the reactivity impact from Boron Injection during an ATWS transient.

(c) Extend the AA78 slip/void correlation for pressures up to 12 MPa.

Further this information has substantial commercial value as follows:

(a) Westinghouse can use its methodology capability to further enhance their licensing position over their competitors.

(b) Assist customers to obtain license changes.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar technical evaluation justifications 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 for developing the enclosed improved core thermal performance methodology.

Further the deponent sayeth not.

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ABSTRACT

The main purpose of this second supplement to the BISON topical report, RPA 90-90-P-A, "BISON – One Dimensional Dynamic Analysis Code for Boiling Water reactors," Reference 1, is to document how BISON, in combination with an approved containment code, can be used to calculate a conservative containment response during an anticipated transient without scram (ATWS).

To enable such calculations, the following three perspectives need to be described, none of which were covered in the original topical report for BISON, Reference 1, or the first supplement, CENPD-292-P-A, "BISON – One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," Reference 2. These new perspectives covered by the second amendment are:

- To increase the maximum approved upper pressure and steam quality limit with respect to the void correlation used.
- To add reactivity impact from Boron during transients.
- To provide an example of an ATWS calculation using the BISON code.

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ACRONYM

1D	Modeling core with single channel and one dimensional kinetics
3D	Modeling core with parallel channels and three dimensional kinetics
ARI	Alternate Rod Insertion
ATWS	Anticipated Transients Without Scram
Bconc	Boron weight concentration in Boron solution
BISON	Westinghouse transient analysis 1D code, see Reference 1
Bmass	Total available Boron Solution mass that can be inserted
BOC	Beginning of Cycle
Bppm	Boron concentration in the reactor water
Bppm0	Initial (steady state) Boron concentration in the reactor water
CPR	Critical Power Ratio
CRD	Control Rod Drive System
D1	Fast diffusion constant
D2	Thermal diffusion constant
D4.1.2	Westinghouse SVEA-96 Optima2 CPR correlation
DC	Downcomer
EB	Boron efficiency factor
EBc	Boron conservativeness factor
EB3d	Boron 3D core correction factor
EOFP	End of Full Power
EOP	Emergency Operating Procedures
EFPH	End of Full Power Hours
FSAR	Final Safety Analysis Report
GOTHIC	Containment analysis code
HPCI	High Pressure Coolant Injection System
HSBW	Hot Shutdown Boron Weight
k_{eff} (0 ppm)	k_{eff} with no Boron concentration
k_{eff} (x ppm)	k_{eff} with a Boron concentration of x ppm
LTR	Licensing Topical Report
MB	Total inserted Boron solution
MBe	Total effectively inserted Boron solution
mBs	Boron solution flow rate
MOC	Middle of Cycle
Mrpv	Total water mass in the rector pressure vessel including the drive loops
MSIV	Main Steam Isolation Valve
ntot	Total number of thermal hydraulic volumes in BISON
OLMCPR	Operating Limit Minimum Critical Power Ratio
pcm	Percent million
POLCA7	Westinghouse in core fuel management 3D code
ppm	Parts per million
PRFO	Pressure Regulator Failure, Open to maximum demand
RCIC	Reactor Core Isolation Cooling system
RPT	Recirculation Pump Trip
RPV	Reactor Pressure Vessel

ACRONYM (cont.)

SER	Safety Evaluation Report
SLCS	Standby liquid control system
SLMCPR	Safety Limit Minimum Critical Power Ratio
TBV	Turbine Bypass Valve
TCV	Turbine Control Valve
V(i)	Volume of thermal hydraulic volume i
$\alpha(i)$	Void fraction in thermal hydraulic volume i
Δk_{eff}	Differential impact on k_{eff} from Boron
$\rho_f(i)$	Density of water in thermal hydraulic volume i
$\sum$	Nuclear cross-section or diffusion constant
$\sum$base	Nuclear cross-section or diffusion constant derived as described in References 1 and 3, all described methods can be used
$\sum$B	Nuclear cross-section or diffusion constant for the second data set with Boron
$\sum$nB	Nuclear cross-section or diffusion constant for the second data set without Boron
$\sum$a1	Fast absorption cross-section
$\eta\sum$f1	Fast fission cross-section times yield
$\sum$r1	Removal cross-section
$\sum$a2	Thermal absorption cross-section
$\eta\sum$f2	Thermal fission cross-section times yield

1 INTRODUCTION

The Westinghouse transient analysis methods are described in the Licensing Topical Reports (LTRs) RPA 90-90-P-A, "BISON – One Dimensional Dynamic Analysis Code for Boiling Water Reactors," Reference 1, and CENPD-292-P-A, "BISON – One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," Reference 2.

RPA 90-90-P-A describes the BISON transient code and the code qualification for BWR transient analyses and was approved for use in license applications by the U.S. NRC in 1989. CENPD-292-P-A was submitted to introduce changes and upgrades to the methods in order to address some of the SER conditions on the original LTR. The second LTR was approved in 1995.

The transient analysis design bases and overall reload methodology are summarized in the Reference Safety Analysis Report for BWR Reload Fuel, Reference 3. The methodology is currently used by Westinghouse for introducing new fuel designs into nuclear power plants in the US.

The main purpose of the second supplement to the BISON topical report, Reference 1, is to extend the applicability of the code to the analysis of ATWS sequences beyond the peak pressure calculations performed today and to determine the mass and energy release to the containment during the Boron injection phase of the accidents.

This report is structured to complement and augment the original LTR and its supplement described above with the following specific features:

- To extend the maximum approved upper pressure and steam quality limit for the AA78 slip/void correlation.
- To model the reactivity impact from Boron injection during an ATWS transient.
- To describe an example of ATWS calculations during the Boron injection phase with the BISON code.

The AA78 slip/void correlation was qualified up to a pressure of 10 MPa (1450 psia) in Reference 1 by comparing the results obtained with the AA78 slip/void correlation to the results obtained using the EPRI slip/void correlation described in Reference 6 {See LTR-NRC-07-15 for justification of change}. NRC SER Condition 4 in the topical report RPA 90-90-P-A requires justification if the AA78 slip/void correlation is used above 1450 psia. The approved range of applicability covers most of BWR applications in the US, including the ASME over pressurization analyses. However, the peak pressure acceptance criterion for the ATWS analysis at BWR/3 plants [ ]^{a,c} is as high as [ ]^{a,c} and therefore it is necessary to extend the range of application of the slip/void correlation to cover pressures above 1450 psia. The justification of the AA78 correlation extension is given in Chapter 3.

The Boron concentration model is described in Chapter 4, its validation in Chapter 5 and the example how to use the model in Chapter 6.

2 THE BASIC MODEL

The physical and thermal-hydraulic models of the BISON code are described in Reference 1, Chapters 2 and 3. Amendments to the model are described in Reference 2.

Boron solution is not accounted for in the thermodynamic model since the Boron solution volume flow is not added to the volume of the water in the Reactor Pressure Vessel Model. Hence all descriptions of the physical model and the thermal-hydraulics as presented in References 1 and 2 are unaffected by the introduction of the present Boron model.

The neutron kinetics model and the different methods available to generate cross-sections for the kinetics model are described in Reference 1, Chapter 4 and are modified with this supplement. In the kinetics model an additive Boron reactivity model will be used. Additional details are provided in Chapter 4.2.

3 JUSTIFICATION FOR SLIP AND VOID CORRELATION IF PRESSURE EXCEEDS 1450 PSIA

The AA78 slip correlation is described in the BISON Topical Report, Reference 1. This correlation is basically a bubble flow correlation modified to cover annular flow as well as for BWR fuel bundles. The mass flux enters explicitly and the pressure only via pressure dependent thermodynamic quantities.

The correlation is a best fit to void measurements performed with full-scale (36 and 64 rods) test sections in the Westinghouse FRIGG test loop. The original recommended range of applicability was:

Pressure:	3.0 to 9.0 MPa (435 to 1305 psia)
Mass flux:	500 to 2900 kg/m^{2}s (0.30 to 2.1 Mlb/h-ft^2)
Steam quality:	0 to 1.0

Covered ranges in these early FRIGG void measurements were:

Table 3-1 Covered Ranges in the AA78 Data Base

Test Section	Pressure (MPa)	Mass Flux (kg/m^{2}s)	Steam Quality (%, max)	Void Fraction (%, max)
0F-36	3.0-9.0	550-2900	40	90
0F-64A	4.8, 6.8	500-2500	40	90
0F-64B	6.8	500-2000	55	95

Additional void measurements were later performed for SVEA-96 geometries (sub-bundle test sections) with lower mass flux values and extended the lower limit to 400 kg/m^{2}s. The void predicted by the AA78 correlation was compared to these new measurements and extrapolation below the data range for mass flux is considered acceptable at least down to 400 kg/m^{2}s.

This new data covered the following ranges:

Table 3-2 Additional Void Measures Utilized for Verification & Validation of the AA78 Void Correlation a,b,c

The error distribution and standard deviation for the AA78 void correlation as a function of the void is shown in Table 3-3 and the comparison against each measurement series in Table 3-4.

Table 3-3 Error Distribution as a Function of the AA78 Predicted Void a,c

Table 3-4 Mean Error and Standard Deviation of the AA78 Predicted Void Compared to the Measured Void for the Different Series a,b,c

EPRI Void Correlation

The EPRI void correlation is based on a larger data base which includes not only rod bundle measurement but also measurements from heated rectangular channels and round tubes. The description of the correlation is given in Reference 6. The statistical Analysis of the Model versus Data for the different types of measurements is provided in Tables 3, 8, and 11 of the EPRI report and summarized in the following table. In addition, Table 13 in Reference 6 gives the Model versus Data – Pressure and Flow Range Comparison and is shown in Figures 3-1 and 3-2 for information.

Table 3-5 Mean Error and RMS Error of the EPRI Predicted Void Compared to the Measured Void for the Different Type of Experimental Data

Experimental Data	Mean Error	RMS Error σ	Sample Size
Rod Bundles	-0.0002 ± 0.0010	0.028	784
Rectangular Channels	-0.0021 ± 0.0018	0.051	776
CISE Tube Data	-0.0007 ± 0.0010	0.022	440

During the NRC review of the BISON Topical Report Reference 1, questions regarding the void models were discussed further. Some of the information provided in responses to the Request for Additional Information is relevant to the discussion of the applicability of the correlation to pressures higher than 9 MPa.

Question 5 regarding the limitations of several correlations, AA78 among them, was answered in Reference 1 pages Q5-1 to Q5-6 and included comparisons with FRIGG loop data. The following text has been extracted from the answer regarding the AA78 void correlation.

"The verified data range covers most BWR applications. However, in some extreme cases, such as design basis pressurization transients (MSIV closure without position scram) or trip of all recirculation pumps, the limits of the above data range may be exceeded. However, the dependencies in pressure and mass flux are smooth and continuous, and the correlation prediction outside the above range follows the expected trend."

To justify that extrapolation beyond the test conditions is acceptable two figures, Q5.1 and Q5.2, were provided. Figure Q5.1 plots measured void against steam quality for two pressures, 7 and 9 MPa (1015 and 1305 psia), at the same inlet subcooling. Also shown are the BISON calculated curves for various pressures. These calculated curves show that there is a smooth trend in void as a function of pressure. Figure Q5.2 shows measured versus calculated void at different pressures, and demonstrate that there is no significant trend in the error as a function of pressure.

Question Q24 requested further justification of the use of the void and boiling correlations in BISON at pressures higher than 9 MPa.

Comparison with other correlations with somewhat larger range of applicability has verified that the correlation behavior is also correct outside the above ranges. Further discussion and justification is provided by the answer to NRC Question 24 in Reference 1, pages Q24-1 to Q24-6. Comparative graphs of pressure trends up to 10.0 MPa and steam qualities up to [ ]^{a,c} were presented. The graphs compare void change trends predicted with AA78 combined with the Solberg boiling/condensation model and with the Lellouche-Zolotar EPRI slip correlations described above.

The EPRI correlation has been verified for a wide range of pressures. It was developed to fit not only the rod data which forms the basis of the AA78 correlation, but also other data including measurement in rectangular channel experiments at 10.3 and 11.0 MPa (1493 and 1598 psia). Thus, it serves as a reference for the variation of void fraction with pressure for a range of geometries.

The following text has been extracted from the answer to Question 24:

"... Figure Q24.1 shows the total change of void fraction with increasing pressure starting at 7 MPa, at constant steam quality, as calculated using the Lellouche-Zolotar correlation, for typical BWR channel conditions. For example, at steam quality 0.2, the void fraction at 8 MPa is approximately 0.025 smaller than that at 7 MPa, and at 10 MPa, the void fraction is approximately 0.075 smaller than that at 7 MPa.

Comparison of this figure with the corresponding curves calculated with AA78 and the Solberg models using parameters derived for a single channel application (Figure Q24.2), and using parameters for application to core average conditions (Figure Q24.3), and also with curves calculated using the modified Bryce-Holmes correlation (Figure Q24.4), indicates that the change of void fraction with pressure over the range 7 to 10 MPa is the same for all methods."

The application of the AA78 void correlation to pressures up to 10 MPa was justified through the answer to Questions Q5 and Q24.

The matter was further discussed in the first supplement to Topical Report, Reference 2. This supplement to the BISON topical report was submitted, among other improvements, to change the boiling and condensation model (core void profile) from Solberg to EPRI. The EPRI boiling/condensation model is a more mechanistic, generic model and independent of the fuel type while the Solberg model is an empirically fit formulation requiring specification of three constants. The selection of these constants assured that the BISON axial coolant density matched the POLCA7 three dimensional core simulator calculated average profile.

The qualification was provided in Section 6.5.3.2 (comparison against the Peach Bottom Turbine Trip data) and in Appendix A in the answer to NRC Question A1 in Reference 2. The same qualification as the one performed in response to Question Q5 in Reference 1 was repeated for the EPRI boiling/condensation model in combination with the AA78 slip (void) correlation. The results of the prediction against the FRIGG loop data are presented in Figures A1-1 and A1-2. These figures show that the correlations give comparable results with no systematic deviations over the entire range of void fractions up to 93%.

To calculate the pressure response during an ATWS up to the acceptance criterion of [ ]^{a,c} psia, a relative small increase in the approved maximum pressure extrapolation is required (about [ ]^{a,c}). To avoid similar problems in the future, a new upper limit of [ ]^{a,c} is suggested. This range increase is supported by extended comparative graphs of the same type as the ones presented in the answer to Question 24 in Reference 1, and are shown in Figures 3-1 and 3-2.

The two differential voids versus steam quality figures for AA78 and EPRI respectively, show that both correlations have exactly the same trends. The differential void at 8.0 MPa (compared to 7.0 MPa) has its maximum at about [

]^{a,c}

The AA78 correlation is, as shown above, verified against measured data for pressures up to 9.0 MPa. In Figure 6-4 of Reference 2, the RMS error of the AA78 correlation as implemented in BISON is [ ]^{a,c} by direct comparisons to measurement data. The mean error is [ ]^{a,c}. When extrapolating further, a comparison with the EPRI correlation is used.

The EPRI void correlation (equivalent to the Chexal-Lellouche drift flux correlation) is described in Reference 8. In this paper, void fraction results were compared to a wide range of experimental data with various geometry, inlet subcooling, power distribution, and pressure values (up to 15 MPa = 2176 psia).

Comparing the differential void changes versus [

]a,c generates the following graphs:

a,c

[

]

As can be noted, [ ]a,c with increasing pressure.
[

]a,c

P ≤ 9.0 MPa [ ]a,c

RMS Error: [ ]a,c

Mean Error [ ]a,c

As can be noted the [
]a,c.

The major explanation for [

]a,c At increased pressure the steam/water density ratio changes with well known pressure dependence (from steam/water tables) for both correlations.

The conclusion of the comparison against experimental data provided in the answer to Questions Q5 and Q24 in Reference 1 demonstrates that there is a smooth trend in void as a function of the pressure and that there is no significant trend in the error as a function of pressure. Therefore there is not a significant increase in the uncertainties due to extrapolation of the correlation to pressures higher than those included in the data base (up to 9 MPa). This is confirmed by comparing the AA78 void to other void correlations based on experimental data for a wider range of pressures, similar to the EPRI void correlation which includes measurements up to 11 MPa. Also Table 13 in Reference 6 shows the lack of trend in the Model versus Data bias with pressure. The comparison between AA78 void correlation to other methods as

shown in Figures Q24.1 to Q24.4, and also presented in Figures 3-1 and 3-2, indicate that the change in void fraction with pressure predicted over the range 7 to 12 MPa is the [ ]a,c.

At uprated power conditions with increased flow window, the core average void is expected to increase since the core average power is higher even though the sub-cooling also increases due to increased feed water flow. However, the highest void fractions occur in the hot channels. The hot channels at EPU conditions still have about the same exit void fraction, since they are limited by the thermal limits, e.g., CPR, that limit the bundle power. At EPU conditions the highest power channels have practically unchanged exit void fractions. The main difference at uprated power conditions is that more channels have higher powers.

For this reason, all correlations valid at high voids (e.g., AA78 which is based on rod bundles void measurements up to 93% void) are still within range at EPU conditions. Further justification of the applicability of the void correlation to EPU conditions and the comparison of the POLCA7 predicted void to the more recent FRIGG measurement for SVEA-96 Optima2 is provided in the answer to Question 13 in Reference 9.

a,c

Figure 3-1 Comparisons of Void Changes as a Function of Steam Quality at Different Pressures

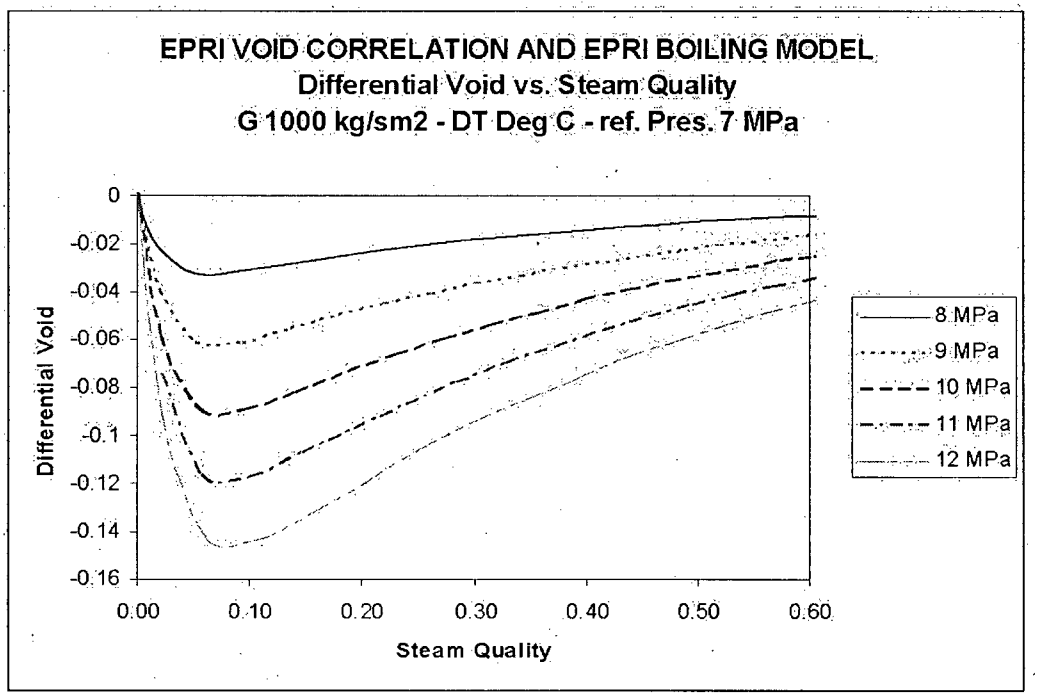

Figure 3-2 Comparisons of Void Changes as a Function of Steam Quality at Different Pressures

4 THE BORON MODEL

4.1 BORON CONCENTRATION MODEL

The Boron concentration model calculates the Boron concentration in the reactor vessel based on a Boron solution insertion flow rate, a Boron mass fraction, an available total Boron solution mass, a methodology penalty factor and a core simulator correction factor to account for actual core contents and 3D effects in the Boron reactivity worth.

To obtain the concentration of Boron in the reactor pressure vessel a conservative approach denoted "perfect mixing" is used. In this model the total water volume is used to derive the concentration based on the total water mass in the reactor vessel.

[

]a,c This conservative approach is explained in detail for the application example in Section 6 of this report.

[

]a,c the "perfect mixing" model will generate a conservative Boron concentration in the core.

4.1.1 Available Boron Mass in the System

The following parameters are given as input to the Boron injection model in BISON:

[

]a,c

The total inserted Boron solution, MB, at any given time t is now:

$$MB = Bconc * \min(Bmass, (\int_{t0}^{t} mBs * dt)) \tag{4.1}$$

To assure conservative calculations an additional factor, EB, always less than one, is also applied and an effective total amount of inserted Boron, MBe, is calculated as:

$$MBe = EB * MB \tag{4.2}$$

EB accounts for two different effects:

[

]a,c

At each time t during the transient the total water mass Mrpv is calculated as:

$$Mrpv = \sum_{i=1}^{ntot} v(i) * (1 - \alpha(i)) * \rho_f(i) \tag{4.4}$$

where

ntot	total number of thermal hydraulic volumes in BISON	(-)
v(i)	volume of thermal hydraulic volume i	(m^3)
$\alpha(i)$	void fraction in thermal hydraulic volume i	(-)
$\rho_f(i)$	density of water in thermal hydraulic volume i	(kg/m^3)
Mrpv	total water mass in the reactor pressure vessel including the drive loops	(kg)

4.1.2 Boron Concentration Model

The Boron concentration in ppm, Bppm, is calculated as:

$$Bppm = 1.E6 * MBe / Mrpv \tag{4.5}$$

This concentration is transferred to the kinetics model to calculate the reactivity impact from Boron.

To simplify comparisons with static codes (3D core simulators, e.g., POLCA7) of Boron reactivity impact, the possibility to give the initial Boron concentration (steady state) as input to the BISON code is added. This parameter, Bppm0, modifies Equation 4.5 to:

$$\text{Bppm} = \text{Bppm0} + 1.\text{E6} * \text{MBe} / \text{Mrpv} \tag{4.6}$$

Combining Equations (4.1) to (4.6), we now obtain:

$$\text{Bppm} = \text{Bppm0} + \frac{1.\text{E6} * \text{EBc} * \text{EB3d} * \text{Bconc} * \min\left(\text{Bmass}, \left(\int_{t0}^{t} \text{mBs} * dt\right)\right)}{\sum_{i=1}^{ntot} v(i) * (1 - \alpha(i)) * \rho_f(i)} \tag{4.7}$$

4.2 NEUTRON KINETICS MODEL

The Neutron kinetics model as described in Section 4 in Reference 1 is not changed with respect to basic equations and nuclear cross-section models.

In addition to the description in Reference 1, [

]^{a,c}. A short summary of the kinetics model described in Reference 1 is given in Section 4.2.1 below.

4.2.1 Basic Model

The neutron kinetics model used in BISON is a time-dependent two-group diffusion model with one-dimensional (axial) space dependence. The neutron kinetics properties of the reactor core are calculated from local cross-sections and delayed neutron data.

Prior to a transient calculation, a steady state is initialized by iterations between the neutron kinetics model and the thermal–hydraulics model until the power distribution and the void and temperature distributions correspond to each other.

Nuclear cross-sections are provided as polynomial functions with a set of coefficients $C_{i,j}$ as described below.

The nomenclature used for the neutron parameters is described as follows:

D_1	Fast diffusion constant	(cm)
Σ_{a1}	Fast absorption cross-section	(cm^{-1})
$\eta\Sigma_{f1}$	Fast fission cross-section times yield	(cm^{-1})
Σ_{r1}	Removal cross-section	(cm^{-1})
D_2	Thermal diffusion constant	(cm)
Σ_{a2}	Thermal absorption cross-section	(cm^{-1})
$\eta\Sigma_{f2}$	Thermal fission cross-section times yield	(cm^{-1})
Σ_{base}	Short hand notation for ANY of the above cross-sections	(different)

Independent variables:

ρ_k	Average moderator density in the region/subsection k
α_k	average void content (steam volume fraction) at the outlet of subsection k
T_{mk}	Moderator temperature assumed equal to the coolant liquid temperature in subsection k
T_f	Mean fuel temperature
T_f^0	Reference fuel temperature
T_m^0	Reference moderator temperature
ΔT_m	$T_{mk} - T_m^0$

General polynomial form:

$$\begin{aligned}\sum_{base} = {} & C_{i1} * (1 + C_{i,5} * \Delta T_m) + C_{i,2} * (1 + C_{i,6} * \Delta T_m) * \rho_k + \\ & C_{i3} * (1 + C_{i,7} * \Delta T_m) * \rho_k^2 + \\ & C_{i4} * (1 + C_{i,8} * \Delta T_m) * \rho_k^3 +\end{aligned} \tag{4.8}$$

Doppler Correction:

$$\sum_{r1} = \sum_{r1}(T_f^0) + C_{1,9} * (1 + C_{1,10} * \rho_k + C_{1,11} * \rho_k^2) * (\sqrt{T_f} - \sqrt{T_f^0}) \tag{4.9}$$

$$\sum_{a1} = \sum_{a1}(T_f^0) + C_{2,9} * (1 + C_{2,10} * \rho_k + C_{2,11} * \rho_k^2) * (\sqrt{T_f} - \sqrt{T_f^0}) \tag{4.10}$$

The Doppler correction includes the fuel temperature influence on Δk from all cross-sections, although only $\sum_{r1}$ and $\sum_{a1}$ are changed in the polynomials. These corrections are calculated by the interface program.

A complete set of polynomials is provided for fuel with no control rods present, and another set with control rods fully inserted for each fuel type.

4.2.2 Boron Cross-Sections

This chapter describes the changes in the neutron kinetics model implemented in order to account for Boron in the model.

The Boron reactivity impact in BISON is assumed to be independent of the fuel or core as long as the ppm value is calculated properly. In order to catch fuel, core and state point specific impact, [

]^{a,c} is provided.

To determine the impact of Boron reactivity, [

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[

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The Boron cross-section model has the following dependencies for each cross-section:

$$\sum = \sum(\rho_c, \rho_{bp}, T_c, Bu, Bppm) \tag{4.12}$$

where

ρ_c	coolant density in the core/bundles	(kg/m^3)
ρ_{bp}	coolant density in the bypass	(kg/m^3)
T_c	coolant temperature	(K)
Bu	burnup	(MWd/kgU)
Bppm	Boron concentration	(ppm)

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[

]a,c is described along with the verification and validation presented in Chapter 5 and used in an application in Chapter 6 of this report.

5 BORON REACTIVITY MODEL VERIFICATION AND VALIDATION

5.1 PURPOSE

To verify that the Boron reactivity model is correctly implemented in BISON a comparison is made against the 3D core simulator POLCA7, Reference 10.

The verification is performed at a typical initial power and recirculation flow when the Boron injection is initiated at a number of different state points and two different cycles.

The verification is also an example of how to obtain the EB3d correction factor based on parallel channels and 3D neutronics. The correction described by Equation 4.3 is applied for different cycle exposures and for different cycles. The use of such a correction factor is further demonstrated and described in Chapter 6 of this report.

The BISON Boron cross-section model uses a SVEA-100 full length fuel as reference fuel. The correct fuel types corresponding to the actual core are hence not modeled explicitly in the cross-sections used by BISON.

The impact of different cores and fuel designs as well as different plants, is taken into account by the 3D normalization factor EB3d. For the normal reactivity based on void and fuel temperatures etc, "method B" as described in Reference 1 is used.

5.2 SELECTED CORES AND STATE POINTS

The state point for this application is selected to be a typical state point just prior to the start of Boron injection for the selected plant. This state point is:

- Thermal Power 591.4 MW
- Core Inlet Temperature 275°C
- Recirculation Flow 3600 kg/s
- Xenon Equilibrium

Two different equilibrium cores were chosen. One of the cores was an equilibrium core with SVEA-96 Optima 2 ("Core A") and the other was an equilibrium core with another fuel type with less number of partial length rods ("Core B") and therefore with a smaller Boron reactivity impact caused by the fewer partial length fuel rods.

5.3 CALCULATIONAL MATRIX

5.3.1 POLCA7

The Boron calculations were made at three different state points:

- BOC
- MOC
- EOFP

The BOC core corresponds to 1000 EFPH, MOC core to 8000 EFPH and the EOFP core to 16000 EFPH.

The calculations were performed for Boron concentrations between 0 - 1200 ppm for "Core A" and between 0 – 900 ppm for "Core B."

5.3.2 BISON

The Boron calculations in BISON were performed at the same state points and Boron concentrations as in POLCA7. The only additional input to BISON is the initial Boron concentration Bppm0, as described in Section 4.1.2 of this report. Only steady state calculations are performed for this validation.

5.4 CALCULATIONAL RESULTS

5.4.1 POLCA7

The results from the POLCA7 calculations are presented in Tables 5-1 to 5-6. The impact on k_{eff} from Boron, Δk_{eff}, is calculated according to:

$$\Delta k_{eff} = (k_{eff\,(0\,ppm)} - k_{eff}) / k_{eff\,(0\,ppm)} \tag{5.1}$$

where

$k_{eff\,(0\,ppm)}$	k_{eff} with 0 ppm Boron concentration
k_{eff}	k_{eff} with a Boron concentration of X ppm
Δk_{eff}	the differential impact on k_{eff} from Boron

The resulting Δk_{eff} are presented in the tables below for both core types ("Core A" and "Core B") at each state point studied (BOC, MOC and EOFP):

Table 5-1 POLCA7 Results for Core A at BOC

a,c

Table 5-2 POLCA7 Results for Core A at MOC

a,c

Table 5-3 POLCA7 Results for Core A at EOFP

a,c

Table 5-4 POLCA7 Results for Core B at BOC

a,c

Table 5-5 POLCA7 Results for Core B at MOC a,c

Table 5-6 POLCA7 Results for Core B at EOFP a,c

5.4.2 Results BISON

The cores are collapsed into BISON. The Boron cross-sections used, are valid for a fuel type with 100 full length rods in each assembly (SVEA-100 core). This will lead to a k_{eff} that differ between BISON and POLCA7 when Boron is simulated through different ppm levels.

The results from the BISON calculations are presented in Tables 5-7 to 5-12. The impact on k_{eff} from Boron, Δk_{eff}, is calculated according Equation 5.1.

The resulting Δk_{eff} values are presented in the tables below for both core types ("Core A" and "Core B") at each state point studied (BOC, MOC and EOFP) respectively:

Table 5-7 BISON Results for Core A at BOC

a,c

Table 5-8 BISON Results for Core A at MOC

a,c

Table 5-9 BISON Results for Core A at EOFP

a,c

Table 5-10 BISON Results for Core B at BOC

a,c

Table 5-11 BISON Results for Core B at MOC

a,c

Table 5-12 BISON Results for Core B at EOFP

a,c

5.5 COMPARISONS BETWEEN POLCA7 AND BISON

The obtained Δk_{eff} values presented for POLCA7 in Section 5.4.1 and for BISON in Section 5.4.2 are now compared as ratios representing the reactivity impact from Boron on the two codes. This ratio, defined as EB3d in Equation 4.3, is calculated as:

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Results are presented in Table 5-13 for "Core A" and Table 5-14 for "Core B."

Table 5-13 EB3d Ratio between Δk_{eff} for POLCA7 and BISON for Core "A" a,c

Table 5-14 EB3d Ratio between Δk_{eff} for POLCA7 and BISON for Core "B" a,c

5.6 DISCUSSION

The BISON core is based a collapsed POLCA7 core, but with Boron differential cross-sections for a SVEA-100 equilibrium core as opposed to SVEA-96 Optima2, that in addition to the difference in core modeling accuracy introduced by the parallel channel modeling in POLCA7 will lead to a difference in the results between BISON and POLCA7.

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5.7 CONCLUSIONS

From the discussion in the previous section, the following overall conclusions can be drawn:

- The BISON Boron model is verified by comparing the impact on the reactivity with POLCA7.
- A 3D correction term in the Boron model can be maintained constant during an ATWS transient since the BISON results show only an insignificant difference in the Boron reactivity impact when compared with POLCA7.

- The use of a generic set of cross-sections adjusted to a specific core and cycle exposure by the EB3d factor in BISON, is shown to be accurate when compared to the results obtained with the 3D core simulator POLCA7. Expected uncertainty is within a [ ]^{a,c} compared to POLCA7 calculations of Δk_{eff}.

- The BISON Boron model is shown to be verified and validated.

6 ATWS APPLICATION

6.1 BACKGROUND

The Westinghouse strategy for handling the ATWS analysis for a reload is based on comparative studies of the plant response through the [ ]a,c of the licensing basis event for a core [ ]a,c. The limiting transient according to the specific plant's licensing basis is used as the reference case for ATWS.

To illustrate the ATWS application when the analysis of the Boron injection phase is included, the event "Pressure Regulator Failure – open to maximum demand" (PRFO) combined with the failure of the scram system is considered. The analysis is performed for a SVEA-96 Optima2 equilibrium core.

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The methodology for the containment analysis is described in a separate topical report.

6.2 ACCEPTANCE CRITERIA

An ATWS event is defined as any anticipated transient event followed by the failure of the automatic reactor shutdown. ATWS events are considered beyond design basis accidents. The acceptance criteria of the design basis accidents are normally applied to the ATWS evaluation. However, ATWS events are not regarded as design basis accidents from other aspects, such as the application of the single failure criterion.

The ATWS acceptance criteria are according to Reference 3 (page 93) the following:

1. Peak reactor vessel bottom pressure less than 120% of vessel design pressure
2. Peak cladding temperature below 2200°F
3. Peak containment pressure shall not exceed Containment Design Limit
4. Dose below Guideline values of 10 CFR 100
5. Demonstrated equipment availability

6.3 CALCULATIONS

The ATWS calculations are divided into three phases. In the first phase [

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[

]a,c Figure 6-1 shows the three different phases of the calculations.

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Figure 6-1 The Three Phases of the ATWS Calculation

6.3.1 Phase One

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]a,c Figure 6-2 shows the Peak RPV bottom pressure obtained with the cross sections calculated with methods B and C. Figure 6-3 shows the integrated flow through the relief and safety valves and Figure 6-4 shows the average core power.

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Figure 6-2 Peak RPV Bottom Pressure, Cross Sections Calculated with Methods B and C

a,c

Figure 6-3 Integrated Flow Thorough Relief and Safety Valves, Cross Sections Calculated with Methods B and C

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Figure 6-4 Average Core Power, Cross Sections Calculated with Methods B and C

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6.3.2 Phase Two

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An example of the peak pressure calculation for a hypothetical plant A and "Core A" is given in Figure 6-5. The peak pressure at the bottom of the reactor vessel is shown for three different burnups: Beginning of Cycle (BOC), Middle of Cycle (MOC) and End of Full Power (EOFP). The acceptance criterion (1500 psig for this particular case) is also shown.

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Figure 6-5 Example of Peak Pressure Calculation

Other key parameters are shown in Figure 6-6.

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Figure 6-6 Steam Flow, Average Core Power, Void and Core Flow

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a,c

Figure 6-7 CPR Curve and Time when Dryout Occurs

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]a,c An example of the peak cladding temperature is shown in Figure 6-8.

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Figure 6-8 Peak Cladding Temperature

6.3.3 Phase Three

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a,c

Figure 6-9 Different Steps of the ATWS Transient Calculations

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]a,c The core flow is shown in Figure 6-12 and the relative core power is shown in Figure 6-13.

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Figure 6-10 Steam Flow from Reactor and Flow through Relief and Safety Valves

a,c

Figure 6-11 Steam Dome and RPV Bottom Pressure

a,c

Figure 6-12 Core Flow

a,c

Figure 6-13 Relative Core Power

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BISON calculates the flow through the relief and safety valves and the energy released to the suppression pool during the whole transient as shown in Figure 6-16 and in Figure 6-17.

a,c

Figure 6-14 Amount of Boron Solution Injected

a,c

Figure 6-15 Downcomer Two-Phase Water Level

a,c

Figure 6-16 Integrated Flow through Relief and Safety Valves

a,c

Figure 6-17 Amount of Energy Released to the Suppression Pool

The Benchmarking of BISON versus POLCA7 for the Boron calculations is described in Section 5 of this report.

[

]a,c The suppression pool temperature for the example considered here is shown in Figure 6-18.

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Figure 6-18 Suppression Pool Temperature

6.4 CONSERVATIVENESS OF THE PERFECT MIXING MODEL

Figure 6-19 shows the conditions in the reactor during an ATWS after the feed water pumps are tripped and the water level in the downcomer has been reduced to slightly above the top of the active fuel.

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Figure 6-19 Thermal Hydraulic Conditions in the Reactor Pressure Vessel during ATWS

7 SUMMARY

The main purpose of this second supplement to the BISON topical report, Reference 1, is to extend the applicability of the code to the analysis of ATWS sequences beyond the peak pressure calculations performed today to determine the mass and energy release to the containment during the Boron injection phase of the accidents.

This report is structured to complement and augment the original LTR and its supplement described above with the following specific features:

- To extend the maximum approved upper pressure and steam quality limit for the AA78 slip/void correlation.
- To model the reactivity impact from Boron injection during an ATWS transient.
- To describe the application of BISON to ATWS calculations during the Boron insertion phase.

The boron reactivity model implemented uses a conservative modeling of the concentration of Boron in the core and generates conservative mass and energy released to containment. The conservatism achieved is based on two major contributions

[

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8 REFERENCES

1. Topical Report RPA 90-90-P-A, Rev. 0, "BISON – A One Dimensional Dynamic Analysis Code for Boiling Water Reactors"

2. Topical Report CENPD-292-P-A, "BISON – A One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," July 1996

3. Topical Report CENPD-300-P-A, Rev. 0, "Reference Safety Report for Boiling Water Reactor Reload Fuel," July 1996

4. Reference deleted {See LTR-NRC-07-15 for justification of change}.

5. Topical Report RPB 90-93-P-A, Rev. 0, "Boiling Water Reactor Emergency Core Cooling System Evaluation Model: Code Description and Qualification"

6. G. S. Lellouche, B. A. Zolotar, "A Mechanistic Model for Predicting Two-Phase Void Fraction for Water in Vertical Tubes, Channels, and Rod Bundles, Electric Power Research Institute," EPRI NP-2246-SR, 1982

7. Reference deleted {See LTR-NRC-07-15 for justification of change}.

8. Paul Coddington and Rafael Macian, "A Study of the Performance of Void Fraction Correlations used in the Context of Drift-Flux Two-Phase Flow Models," Nuclear Science Engineering and Design, 215 (2002) 199-216

9. Letter from P. R. Simpson (Exelon Nuclear) to U.S. NRC, "Request for License Amendment Regarding Transition to Westinghouse Fuel," June 15, 2005

10. Topical Report CENPD-390-P-A, "The Advanced PHOENIX and POLCA Codes for Nuclear Design of Boiling Water Reactors," December 2000

11. Topical Report WCAP-16608-P, "Westinghouse Containment Analysis Methodology," August 2006

12. Quad Cities 1 & 2 FSAR, B 3.1.7 Standby Liquid Control (SLC) System

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Section C

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Our ref: LTR-NRC-07-15
May 14, 2007

Subject: Response to NRC's Request for Additional Information by the Office Of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2925) (Proprietary/Non-proprietary)

Enclosed are copies of the Proprietary and Non-Proprietary clarification responses for NRC's Request for Additional Information for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A."

Also enclosed is:

1. One (1) copy of the Application for Withholding, AW-07-2278 (Non-proprietary) with Proprietary Information Notice.
2. One (1) copy of Affidavit (Non-proprietary).

This submittal contains proprietary information of Westinghouse Electric Company, LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the affidavit or Application for Withholding should reference AW-07-2278 and should be addressed to B. F. Maurer, Acting Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

Enclosures
cc: A. Mendiola, NRR
E. Throm, NRR
R. Landry, NRR
A. Attard, NRR
H. Cruz, NRR
J. Thompson, NRR

Westinghouse

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e-mail: maurerbf@westinghouse.com

Our ref: AW-07-2278
May 14, 2007

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Response to NRC's Request for Additional Information by the Office Of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2925) (Proprietary)

Reference: Letter from B. F. Maurer to NRC, LTR-NRC-07-15, dated May 14, 2007

The application for withholding is submitted by Westinghouse Electric Company LLC (Westinghouse) pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-07-2278 accompanies this application for withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

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

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-07-2278 and should be addressed to B. F. Maurer, Acting Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

B. F. Maurer, Acting Manager
Regulatory Compliance and Plant Licensing

cc: A. Mendiola, NRR
E. Throm, NRR
H. Cruz, NRR
J. Thompson, NRR

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, Acting Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed
before me this 14th day
of May, 2007.

Margaret L. Gonano
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Margaret L. Gonano, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Jan. 3, 2010
Member, Pennsylvania Association of Notaries

(1) I am Acting Manager, Regulatory Compliance and Plant 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 rulemaking 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 which 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 "Response to NRC's Request for Additional Information by the Office Of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, 'Supplement 2 to BISON Topical Report RPA 90-90-P-A' (TAC No. MD2925)" (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-07-15) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse Electric Company is responses to NRC's Request for Additional Information.

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

(a) Demonstrate the transient analysis design bases for use in BWR reload licensing.

Further this information has substantial commercial value as follows:

(a) This methodology is used by Westinghouse for introducing new fuel designs into nuclear power plants in the U.S.

(b) Assist customers to obtain license changes.

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 fuel design 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 for developing the enclosed improved core thermal performance methodology.

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.

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LTR-NRC-07-15 NP-Attachment
TAC No. MD2952

Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2952)

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Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2952)

The following provides the Westinghouse response to the preliminary Request for Additional Information (RAI) sent April 04, 2007 from Jon Thompson (NRR) to Rob Sisk (Westinghouse) and later discussed in a follow-up conference call held on April 20, 2007.

For ease of reference, the RAI opening paragraph and list of references are repeated below, followed by each of the RAI questions and the corresponding Westinghouse response. In those instances where the preliminary RAI questions, in addition to the RAI responses, contain information deemed proprietary for Westinghouse, the information which is proprietary is also contained within brackets. It is requested that this information be treated accordingly.

RAI preface: The report revision proposes to extend the AA78 slip/void correlation for [ ]. This modification was already submitted and approved by the NRC in the Exelon Licensing Agreement (sic Amendment) Request, letter RS-05-78, June 15, 2005. This is included in the report so that it can be approved for generic application to all BWR plants.

References:

1. "Request for License Amendment Regarding Transition to Westinghouse Fuel," Exelon Nuclear, letter RS-05-078, dated June 15, 2005. ADAMS Accession: ML060620352.

2. "Additional Information Supporting Request for License Amendment Regarding Transition to Westinghouse Fuel," Exelon Nuclear, letter RS-06-009, dated January 26, 2006. ADAMS Accession: ML060620365.

3. Letter from M. Banerjee, USNRC, to C.M. Crane, President, Excelon Generation Company, LLC, "Dresden Nuclear Power Station, Units 2 and 3, and Quad Cities Nuclear Power Station, Units 1 and 2 - Issuance of Amendments Re: transition to Westinghouse Fuel and Minimum Critical Power Ratio Safety Limits (TAC No. MC7323, MC7324, MC7325 and MC7326," April 4, 2006. ADAMS Accession: ML060970519.

4 Topical Report RPA 90-90-P-A, Rev. 0, "BISON - A One Dimensional Dynamic Analysis Code for Boiling Water Reactors," ABB Combustion Engineering Nuclear Operations, December 1991.

5. Topical Report CENPD-292-P-A, "BISON - A One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," ABB Combustion Engineering Nuclear Operations, July 1996.

6. G. S. Lellouche, B. A. Zolotar, "A Mechanistic Model for Predicting Two Phase Void Fraction for Water in Vertical Tubes, Channels, and Rod Bundles, Electric Power Research Institute," EPRI NP-2246-SR, 1982.

7. Paul Coddington and Rafael Macian, "A Study of the Performance of Void Fraction Correlations used in the Context of Drift Flux Two Phase Flow Models," Nuclear Science Engineering and Design, 215 (2002) 199-216.

The following references have been added to support the RAI responses. Note that Reference 11 is not included in the references provided in the topical report. A copy of this reference is available on request.

8. WCAP-16606-P, "Supplement 2 to BISON Topical Report RPA-90-90-PA," August 2006.

9. CENPD-300-P-A, "Reference Safety Report for Boiling Water Reactor," July 1996.

10. RPB 90-93-P-A, "Boiling Water Emergency Core Cooling System Evaluation Model: Code Description and qualification."

11. T. G. Theofanous and E. A. Shabana, "Boron mixing in the lower plenum of a BWR," Nuclear Engineering and Design, 126 (1991), p.245-255.

Also during the preparation of the responses to the RAI, the following discrepancies were identified as needing to be corrected in the topical report.

1. A typographical error was recognized in Section 1, INTRODUCTION, paragraph 6 on page 1. The current text includes Reference 7 which should be revised to Reference 6, so that it refers to EPRI report NP-2246-SR (listed as Reference 6 on page 43). The same Reference 6 is correctly stated in Section 3, JUSTIFICATION FOR SLIP AND VOID CORRELATION IF PRESSURE EXCEEDS [ ]^{a,c}, EPRI Void Correlation, paragraph 1 on page 6.

2. The list of references provided on page 43 presently includes References 4 and 7 which are not referenced in the report and should be deleted.

Response to RAIs:

RAI 1:

In Ref. 1 (Attachment 7, page 10 of 32, or page 6 of the submittal), the stated verified steam quality is 20% less than the value presented in Ref. 2 (Attachment 1, page 28 of 46). The staff's SE (Ref. 3) does not address this inconsistency but references the responses in its SE, possibly implying the greater value. Clarify Westinghouse's position on the proposed range for the steam quality for this review.

Response to RAI 1:

The report proposes the following steam dome pressure (P) and steam quality (x) limits:

[ ]^{a,c}

[ ]^{a,c}

If the steam dome pressure exceeds the above proposed limits, then further justification will be supplied.

The proposed limits are consistent with those requested by Exelon License Amendment Request (LAR) dated January 20, 2005 (Reference 1) and the associated RAI Response dated January 26, 2006 (Reference 2). The requested amendments were issued for the Dresden and Quad Cities nuclear power plants on April 4, 2006 (Reference 3).

As noted in RAI 1, the steam quality values provided in References 1 and 2 are different. This is because the value provided in Reference 2 is more recent. The steam quality presented in Reference 2 is the maximum steam quality that supporting calculations have been made for. The verified steam quality provided in Reference 2 therefore supersedes the statement in Reference 1.

Also see the response to RAI 2.

RAI 2:

In the staff SE in Ref. 4, Westinghouse committed to provide justification for the use of the correlation if the pressure exceeds [ ] while the steam quality exceeds [ ], or if the pressure exceeds [ ]. It is also noted that this same condition was identified in the staff SE in Ref. 5. In part, this request addresses the pressure issue, however it is not clear if there is a similar pressure versus steam quality relationship inferred. Clarify if a similar relationship is inferred for this review, for example a quality-pressure limit.

Response to RAI 2:

The report is structured to augment the original LTR by extending the maximum approved upper pressure and steam quality limit for the AA78 slip/void correlation, hence a similar pressure-quality relationship is proposed and based on the following justifications.

As provided in the Response to RAI-1, the proposed new steam dome pressure (P) and steam quality (x) limits are:

[ ]a, c
[ ]a, c

Also, consistent with the current commitment, if the steam dome pressure exceeds the above proposed limits, then further justification will be supplied.

With regard to the proposed pressure limits, both the AA78 and the EPRI void correlations are based on the Zuber-Findlay drift flux model. This drift flux concept is shown to be able to predict void fractions for rod geometries up to 12 MPa in the BWR 8x8 tests and up to 15 MPa for the LSTF tests (Reference 8). It can hence be concluded that an upper pressure limit of [ ]a, c is well covered for rod geometries.

The proposed steam quality range is additionally supported by the following information:

1. The void correlation AA78 is a development of the AA69 void correlation and is based on the same FRIGG data with additional data points added. As described on page 51 in Reference 4, the void correlation AA69 is valid for all void fractions (0-1.0). Hence, the proposed quality range for AA78 is well supported.

2. The importance of the pressure in the void correlation becomes less and less the higher the steam quality is. At a steam quality of 1.0 the void is naturally also 1.0 independent of the pressure.

3. High steam qualities are only expected to occur during pressure decrease transients.

In summary, experience indicates that pressurization transients do not lead to high qualities, especially if the transient is fast. The safety and relief valves would rapidly control the reactor pressure down to well below 9 MPa and into the well verified correlation range; so an upper limit of [ ]^{a,c} in steam quality for a steam dome pressure above 9 MPa would cover the expected conditions during a pressurization transient without scram. Additionally, for all foreseen ATWS applications, the ASME 120% maximum design pressure limit is below 10.5 MPa. Thus, the proposed limits are reasonable for the expected range of applications.

RAI 3:

Figure 14-3 in Ref. 2 (Attachment 1, page 31 of 46) is supposed to be the same as Figure Q24.1 in Ref. 4, based on the plot titles (with the exception that Fig. 14-3 does not provide the specific value for DT as shown in Fig. Q24.1). Fig 14-3 is adding two additional pressure curves and broadening the steam quality range. Fig. 3-2 in the submittal is the same as Fig. 14-3. The two figures (14-3 and Q24.1) are not the same for the original three pressure curves. There is a consistent difference of more than 10% in the peak differentials for the pressure curves. Clarify and explain.

Response to RAI 3:

Both Figure Q24.1 in Reference 4 and Figure 14-3 in Reference 2 have the same titles, "EPRI VOID CORRELATION AND EPRI BOILING MODEL." Also, the inlet subcooling DT value for Figure 14-3 in Reference 2 is 10°C. While these figures are similar, they are not exactly the same.

The maximum differential void impact from the pressure change obtained from the two graphs is as follows:

[ ]^{a,c}

The quality in the above table is given as absolute values, while the void is given as differential void versus 7 MPa.

[ ]^{a,c}

This difference is explained considering how the plots were derived. BISON/SLAVE was used to simulate steady state with the boundary conditions [ ]^{a,c} (in Reference 4 up to [ ]^{a,c}

and in Reference 2 up to [ ]^{a,c}). The graphs are then produced using nodal steam qualities and nodal voids (25 axial nodes).

To reach higher steam qualities, the channel power has to be increased. Since the EPRI boiling model contains terms from the fuel rod heat flux (Reference 2, pages 88-91), this will slightly impact the actual void contents.

The two figures will then be slightly different, but since the aim of the graph is to show trends and not absolute values (they will differ through power and axial power shape impact), the difference does not change the conclusions of similar trends for both void correlations.

RAI 4:

The proposal requests a pressure range that seems to be about 1 to 2 MPa above the test data used to develop the correlation (based on Reference 6), although Reference 4 indicates 1347 FRIGG data points were used but based on an unpublished and therefore unavailable report. In addition, the high pressure range data seems to have come from rectangular channel experiments. Given that the apparent data does not directly support the proposed request, explain why the pressure range should be expanded when the only argument put forth is that all the available correlations are equally unable to account for the change in the void as a function of pressure. There is additional data in Reference 7, but the staff is unable to determine if these data are relevant to the development of the AA78 correlation, other than perhaps supporting the similarity between the other correlation capabilities.

Response to RAI 4:

The following discussion addresses the function of pressure and rod geometries relative to the proposed correlation range.

During a normal AOO like a "Load Rejection without Bypass" or during the pressurization part of "Pressure Regulator Failure, Increasing demand open," the void change that generates the fission power peak is almost entirely a transport phenomenon. When the resulting pressure wave caused by the load rejection reaches the reactor vessel, the reactor pressure rapidly starts to increase. Since the pressure at the core inlet starts to increase, but not the water temperature, the core inlet subcooling starts to increase. As a consequence of the increased subcooling, the boiling in the lower part of the core decreases or even stops. The existing steam in the lower part is transported upwards in the core without any new steam replacing the steam transported away. This phenomenon produces a large void decrease in the bottom of the core and moves the boiling boundary towards the top of the core. This can be observed as a core average void decrease [ ]^{a,c}. The void correlation itself has only a very minor impact on this average core void decrease. Also see the plant data comparison provided as part of the response to RAI 6. Thus, the pressure increase is not modeled as a direct pressure dependent in any of the correlations modeled. Instead, it is the changes in well known pressure dependences in thermodynamic properties that are modeled.

Both the AA78 and EPRI void correlations are based on the Zuber-Findlay drift flux models and adapted to the drift flux model in BISON. In Reference 5, several correlations are compared to measurement data. This includes rod geometries from the BWR 8x8 tests (up to 12 MPa) and the LSTF tests (up to 15 MPa). The Zuber-Findlay correlation shows no systematic pressure dependence even though high voids are not well predicted due to the absence of annular flow modeling in the correlation, which is not the case for AA78 or EPRI where the annular flow

regime is explicitly modeled. The Chezal Lellouche correlation, that is an improved version of the EPRI void correlation (or Lellouche Zolotar), also shows good agreement at higher voids. As can be seen from Reference 8, Figures 3-1 and 3-2, the pressure dependence is similar. It can hence be concluded that the AA78 or EPRI void correlations give very similar void dependences when the pressure is changed.

It can also be noted that the void reduction when pressure increases in AA78 [ ]^{a,c} for EPRI. In a pressure increase transient (the only way to get to high pressure), this difference between the AA78 and EPRI correlation will, [ ]^{a,c} using AA78 instead of using EPRI.

It is also concluded that using AA78, which has been optimized to fuel bundles geometries, will give a [ ]^{a,c} result in fast pressurization transients compared to the EPRI correlation. The EPRI correlation also gives reasonable results though.

RAI 5:

In considering the error propagation as pressure increases for both the EPRI and AA78 (Fig. 14-2, Ref. 2, or Fig. 3-1 in the submittal) correlations, if the EPRI correlation is considered as the reference then explain why the AA78 correlation is appropriate for use in licensing analyses given the error differences between the two correlations. Include a discussion of the uncertainty in the correlation and its treatment for licensing analyses.

Response to RAI 5:

The reason for using AA78 void correlation is that all BISON validation reported in the BISON topical (Reference 2) and topical amendment (Reference 5) are consistently made using AA78. In a non-equilibrium transient code like BISON, the void fraction change from steady state is not the direct result of a void correlation. A void fraction change is a result of changes in the volume cell specific mass, energy and momentum balances due to the transport and boiling/condensation phenomena. Void changes are used to calculate the steam quality that will affect the amount of steam/water transported in and out of each volume cell.

During an AOO like a Load Rejection without Bypass, the void change that generates the fission power peak is almost entirely a transport phenomenon as described in the response to RAI 4.

The actual AA78 RMS does not change when [ ]^{a,c} as shown on page 7 in Reference 8. On the same page there are also two figures showing that the bias between the EPRI and AA78 correlations [ ]^{a,c}.

Any possible impact of the selection of the void correlation is very well covered by the MCPR uncertainty multiplier of [ ]^{a,c} described in Reference 9. This uncertainty evaluation is verified for every plant and every cycle to confirm that the [ ]^{a,c} multiplier is bounding.

RAI 6:

The AA78 correlation is based on pressure, flow rate, quality, heat flux and heated perimeter and hydraulic diameter.

(a) The physical channel characteristics are not addressed. Explain the range of these parameters over which the correlation is thought to be acceptable for licensing analyses, or why the geometry is unimportant even though the geometry is factored into determining the drift velocity as part of the correlation. Also provide a comparison of these values from the tests to those in the nuclear power plant in support of using the correlation.

(b) The heat flux is only noted in Ref. 4 (page 3-15) but not compared to the data base. Explain the range of this parameter over which the correlation is thought to be acceptable for licensing analyses, or why the heat flux is unimportant even though the heat flux is factored into determining the drift velocity as part of the correlation. Also provide a comparison of this value from the tests to that in the nuclear power plant in support of using the correlation.

Response to RAI 6:

The importance of the fuel geometry as such is considered through the heated perimeter and hydraulic diameter. These two parameters directly describe the total heat transfer area (heated perimeter) and indirectly the rod pitch and total box wall area (hydraulic diameter).

No particular range limitation of the heat flux correlation is considered necessary on the steam drift velocity (ugj) described in Reference 4, and only typical values are provided. To support this conclusion, some discussion of the bases for the heat flux correction is needed.

The justification of the heat flux correction is provided in Reference 4. An additional explanation as to why a heat flux correction needs to be applied to the void correlation can be added to what is documented in Reference 4.

[

]a, c

[ ]a,b,

[

]a,c

In 1985, a fast pump runback occurred in the [ ]a,c. This was one of many events that were the bases for the selection of preferred correlations to be used in the BISON code. This event is shown in the graph below, [ ]a,c.

[ ]a,b,c

The event was dynamically analyzed with BISON in 1989 as part of a licensing activity for the [ ]a,c. The simulations were performed using different correlations and different void feedback magnitudes. Results are summarized in the below table.

[ ]a,b,c

[ ]a,c

This shows that AA78 in combination with BISON is the best selection.

Regarding the range of the heat flux correlation, the study on the load line was performed using data from a pump run back from full power at the original plant power and with the original fuel design. The [ ]a,c plant was later uprated in steps so that the present power level is 25% above the original power level. The original power level gives approximately 45 W/cm^2 in core average surface heat flux. After 25% power uprate and change to 10x10 fuel geometry (SVEA-96 Optima), the core average heat flux is almost unchanged.

[ ]a,c	Original	Uprated	
Fuel Type	8x8	S96 Optima	-
Power	2000	2500	MW
Bundles	500	500	-
Fuel rod diameter	[ ]a,c	[ ]a,c	m
Active Length	3.65	3.65	m
Number of rods per assembly	64	96	-
Fuel surface area	[ ]a,c	[ ]a,c	m^2
Average heat flux	[ ]a,c	[ ]a,c	W/cm^2

The overall conclusion for the heat flux correction of the AA78 correlation must therefore be that the impact is quite [ ]a,c Also, power uprated U.S. plants operate at [ ]a,c verification.

Hence no practical upper limit of the heat flux in AA78 is needed. Upper limits are naturally coming from the transient events studied and the limitations of other plant parameters like MCPR.

RAI 7: **(Previously listed as Neutronics–Boron Model Question 1)**

On page 10 of the August submittal, chapter 4 describes the boron model. The boron model assumes the boron to be mixed uniformly throughout the reactor pressure vessel (RPV) water inventory.

a) no information is provided in this section regarding the boron settling model after the boron was injected. Provide details of the boron settling model. In addition, describe the model in the code used to account for boron settling in the lower vessel head for BWR design with injection below the bottom of active fuel (BAF).

b) Several licensee's emergency procedure guidelines (Pegs) recommend reducing the vessel water level during ATWS events to reduce reactor power.

I) Verify that the boron concentration is based on a RPV water inventory at the nominal vessel level.

ii) Provide a curve showing the fraction of the stand-by control system (SLCS) tank injected as a function of time for a limiting RPV pressure.

Response to RAI 7:

There is [

]a,c This value is an input value provided by the plant based on the analysis of record before the fuel transition.

According to a work performed in the University of California presented in Reference 11, Boron mixing may not be perfect if the flow at the SLCS injection location is too low. According to the mentioned reference, a minimum flow equivalent to 8.2% of the rated recirculation flow is needed to obtain 100% mixing.

According to Figure 6-12 of WCAP-16606-P, [

]a,c

In addition to the [

]a,c

It is hence concluded that following the ATWS emergency procedures in the simulations gives sufficient conservatism in the simulation [
]a, c

The requested graph is shown as "Amount of Boron Solution Injected" in Figure 6-14.

RAI 8: **(Previously listed as Question 2)**

On page 12 of the August submittal, Section 4.2 of the topical report states that the kinetic model is based on a one axial dimensional model. To help the staff understand this model, additional details of the kinetics model are required.

a) **Specifically address the influence of the reactor adjoint on prompt nuclear feedback for boron injection into either the top of the core (for SLCS injection above the TAF), and into the bottom of the core (for SLCS injection below the BAF).**

b) **At certain points in core life the flux adjoint in the upper axial parts of the core is very low. In cases where SLCS injection is below the BAF, describe the conservatisms in the methodology that ensure that the boron worth is adequately predicted, considering that boron will preferentially migrate from the lower head bundles with a lower two phase pressure drop (i.e. low power bundles) where the flux adjoint is low.**

c) **Provide a discussion of the model conservatism in terms of boron settling, reduction of vessel level per EPGs. If possible, provide a best estimate comparison of the time dependent suppression pool cumulative heat load and temperature, neutron power, and integrated boron predicted using a transient plant code with a three dimensional kinetics model to best estimate BISON results.**

Response to RAI 8:

The adjoint flow is of interest only in point kinetic models. The BISON kinetic model is a two-group one dimensional axial model that can predict the fast and thermal fluxes based on nuclear cross-sections. The axial power shape during transients, like in e. g. the ATWS scenario in the application example, will hence change according to the changes in the core conditions during the accident. Since the Boron concentration is also an axial property, the Boron impact is also accounted for axially.

In the ATWS application example, the start of the Boron injection is simulated using the adequate SLCS initiation times according to the plant EOP, [

]a, c

For plants with SLCS insertion below BAF, the Boron in the core bottom will have the largest effect on the power since this part of the core has a low void fraction and therefore high Boron contents since the Boron dissolves only on the water phase.

[

]a, c

For more on the boron modeling, please see the response to RAI 7 above.

3D calculations are not available for the ATWS scenario described. More information about the 3D effects are provided in the responses to RAI 12 and 13.

RAI 9: **(Previously listed as Question 3)**

Following the multiple RPTs after an ATWS signal, BWRs are likely to undergo power oscillations due to the high power to flow ratios.

a) Describe the aspects of the BISON methodology that ensure that 10 CFR 100 limits are conservatively met. Specifically address:

i) the adequacy of the kinetic model to predict core wide oscillations under non-isolation ATWS events,

ii) the kinetic model aspects that addresses the regional oscillations for larger cores,

iii) post dry-out heat transfer calculational abilities or conservative treatment of critical heat flux for EPU cores with flat power distributions, and any inherent conservatism in the suppression pool heat load.

iv) Provide, where applicable, the assessment of specific models to plant or experimental data, such as the LaSalle dual RPT event.

Response to RAI 9:

For GE built BWRs, the stability evaluation during ATWS was generically dispositioned based on mitigation actions included in the plant EPGs. Westinghouse methodology preserves the plant licensing basis regarding these mitigation actions and takes them into consideration in the BISON simulation of the ATWS events.

[ ]a, c

[

]a, c

[

]a,c

The above requirements are met with the steady state 3D thermal hydraulic collapse methodology, which is the methodology utilized for the transient analysis.

[

]a, c

For regional oscillations, a 1D model can naturally not predict such variations, but the containment loads and the peak pressures are not affected if the average values are not affected. Only the possible occurrence of dryout and its timing, and therefore the maximum cladding temperature, can be affected.

The post dryout heat transfer is modeled using max Bromley, Groeneveld according to the conservative approach described in RPB 90-93-P-A, "Water Reactor Emergency Core Cooling System Evaluation Model: Code Description and Qualification," October 1990 (Reference 10).

[

]a, c

Dryout occurs early in the transient (when the power is still relatively high) while global or regional oscillations may occur later in the transient after the RPT. The possible occurrence of dryout during power/flow oscillations is hence conservatively covered by not taking credit of dryout/quenching.

RPT validation is supplied in RPA 90-90-P-A (Reference 4, section 4, pages 345-362, plus answer to Q15, Q16, Q17, Q18 and Q19 on pages 410-415) for an all recirculation pump trip test performed during commissioning of the [ ]a, c

In addition, in CENPD-292-P-A (Reference 5) a single pump trip on a BWR/5 is compared to measurement data (Appendix F, pages 169-176).

Both RPT simulations are in good agreement with measurement data. In the [ ]a, c case the single channel model SLAVE (used to evaluate single channel responses, e.g. CPR) are validated. This validation has been possible due to the unique feature of ASEA Atom designed BWR where measured channel flows are recorded for individual instrumented channels.

RAI 10: (Previously listed as Question 4)

On page 17 of the August submittal, the acronym "EOFP" is used. Is EOFP the same as EOL or EOC?

Response to RAI 10:

EOFP is End of Full Power (Life) defined as the cycle exposure at which the core can no longer maintain the target thermal power at rated core flow, with no implementation of feedwater temperature reduction.

RAI 11: (Previously listed as Question 5)

On page 17 of the same submittal, section 5.4 presents the comparison results of the boron calculations by BISON against those of POLCA7 on separate pages. Provide a one/two/three? page Table comprising the calculational results of BISON and POLCA7, (the results already presented in Tables 5-1 through 5-12) and a side by side format for each plant and time of cycle. On the same pages, please provide the difference in the Dk_{eff} between BISON and POLCA7 results in percentage format.

In addition, provide plots of the BISON and POLCA7 results for each plant and time of cycle, stating if the BISON results are more conservative and why.

Response to RAI 11:

Two updated tables based on Table 5-1 through 5-12 are supplied below:

The "Diff" in the tables below is Δk_{eff} from BISON subtracted to Δk_{eff} from POLCA, divided with Δk_{eff} from POLCA and multiplied with 100.

[ ]a,c

[ ]a,c

For a more detailed explanation please refer to the response to RAI 7.

RAI 12: (Previously listed as Question 6)

On page 25 of the August submittal, the first paragraph in section 5.6 is confusing to the staff. It is possible that there are sentence structure issues. Please provide additional clarification.

Response to RAI 12:

The BISON core model is based on a collapsed POLCA7 core. Nuclear cross sections and their dependences are also collapsed from POLCA7.

[

]a, c

RAI 13: (Previously listed as Question 7)

In the concluding section of chapter 5, section 5.7, the first paragraph on page 26, the last sentence states that the expected uncertainty is within a few percent in comparing the BISON results with those of POLCA7 results. Please tabulate these uncertainties and provide plots for each plant and cycle time, demonstrating these few uncertainties, and again, state whether these uncertainties are in the conservative direction, and why.

Response to RAI 13:

The reasons for deviations between POLCA7 (accurate core modeling) and BISON [
]a, c are several:

[

]a, c

[

]a, c

[ ]a,c

[

]a, c

[ ]a,b,c

[ ]a,b,c

The parallel channel effects on the Boron worth can be seen from the different reactivity ratio obtained at different times in the cycle from beginning of cycle (BOC) through middle of cycle (MOC) until end of full power life (EOFP). The Boron worth evaluated as (Eb3Dmax-Eb3Dmin)/Eb3Dmin is summarized in the following table:

[ ]a,b,c

[

]a,c

[ ]a,b,c

As can be seen in the above table, the uncertainty is [ ]a,c

To account for all these effects and to do it conservatively, the minimum value of Eb3D is selected at each time in the cycle.

RAI 14: **(Previously listed as Question 8)**

It is not clear from the submittal whether the void correlation was developed based on high void fractions (>90%) for current fuel. Tables 3-1 and 3-2 allude to high void fractions, but for low flow and low pressure. Please provide technical justification for application of the void correlation to an ATWS event which is a high pressure event.

Response to RAI 14:

The correlation AA69 is valid for [ ][a, c] according to the description on page 51 in RPA 90-90. The void correlation AA78 is based on the same FRIGG data but additional data points have been added. It is hence reasonable to apply the same quality range to AA78.

Pressure range shown in Tables 3.1 and 3.2 is [ ][a, c] which is the expected range of the ATWS event at high pressure. Justification of the application of the void correlation to the ATWS scenario is provided in section 3 of Reference 8 and in the answer to questions 1 to 6 above.

Section D

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Our ref: LTR-NRC-07-34
July 26, 2007

Subject: Clarification Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2952) (Proprietary/Non-proprietary)

Enclosed are copies of the Proprietary and Non-Proprietary clarification responses to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A"

Also enclosed is:

1. One (1) copy of the Application for Withholding, AW-07-2308 (Non-proprietary) with Proprietary Information Notice.
2. One (1) copy of Affidavit (Non-proprietary).

This submittal contains proprietary information of Westinghouse Electric Company, LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the affidavit or Application for Withholding should reference AW-07-2308 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
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Enclosures
cc: A. Mendiola, NRR
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Our ref: AW-07-2308
July 26, 2007

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-07-34 P-Enclosure, "Clarification Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, 'Supplement 2 to BISON Topical Report RPA 90-90-P-A' " (TAC No. MD2952) (Proprietary)

Reference: Letter from J. A. Gresham to Document Control Desk, LTR-NRC-07-34, dated July 26, 2007

The application for withholding is submitted by Westinghouse Electric Company LLC (Westinghouse) pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-07-2308 accompanies this application for withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

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

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-07-2308 and should be addressed to J. A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Cc: A. Mendiola, NRR
R. Lobel, NRR
J. Thompson, NRR

AW-07-2308

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared J. A. Gresham, 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.

PATRICIA L. CROWN COMMONWEALTH OF PENNSYLVANIA NOTARY PUBLIC

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed
before me this 27th day
of July, 2007.

Patricia L. Crown
Notary Public
COMMONWEALTH OF PENNSYLVANIA

Notarial Seal
Patricia L. Crown, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Feb. 7, 2009

Member, Pennsylvania Association of Notaries

(1) I am Manager, Regulatory Compliance and Plant 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 rulemaking 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 which 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 LTR-NRC-07-34 P-Enclosure, "Clarification Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, 'Supplement 2 to BISON Topical Report RPA 90-90-P-A' " (TAC No. MD2952) (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-07-34) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse Electric Company is clarification responses to NRC's Request for Additional Information.

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

(a) Demonstrate the transient analysis design bases for use in BWR reload licensing.

Further this information has substantial commercial value as follows:

(a) This methodology is used by Westinghouse for introducing new fuel designs into nuclear power plants in the U.S.

(b) Assist customers to obtain license changes.

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 fuel design 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 for developing the enclosed improved core thermal performance methodology.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

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

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

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Clarification Response to NRC's Request for Additional Information By the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16606-P, Revision 0, "Supplement 2 to BISON Topical Report RPA 90-90-P-A" (TAC No. MD2952)

Staff comments on the responses to RAIs associated with WCAP-16606-P.

Comment regarding RAI 7

The staff is still concerned regarding the conservative treatment of boron "hold up" in the lower vessel head that may lead to an overly non-conservative calculation for the core average boron concentration.

From the RAI responses, dated May14, 2007, Westinghouse stated that in order to account for boron settling, the analysis conducted by Westinghouse, applies a correction factor of [ ] to the boron concentration. But this factor is determined based on a plant specific analysis. The staff needs to understand the basis for the determination of this correction factor.

The analysis should apply a correction factor that accounts for the following phenomena that are not explicitly treated:

1.Boron precipitation and settling in the lower vessel head.
2.Boron solution stratification and hold-up in the lower vessel head
3.Boron flow into and distribution within the core bypass

The response to RAI #7 indicates, that low flow in the lower head would hamper mixing. The response references a value of recirculation flow of ~ 8.5% that would be sufficient to ensure mixing in the lower head. The response states that [ ] and would therefore be adequate to ensure mixing. The staff does not have sufficient information to reach the same conclusion because the core flow will be a combination of the recirculation flow from the downcomer as well as influx of liquid water from the bypass region depending on the water level in the annulus and specific conditions during the ATWS event. If a major contributor to the core flow comes from the bypass once the level is below the dryer skirt then the staff does not find the basis adequate [ ]

The staff is requesting Westinghouse to provide a demonstration analysis that quantifies the impact of these effects on peak pressure and suppression pool load. The demonstration should explain the correction factor basis and verify that the conservatism bounds any impact on the results based on boron "hold up" or potentially non-conservative results that credit larger than realistic concentrations of boron in the core bypass for lower head SLCS injection BWRs.

Since these phenomena were not addressed in the response, the staff cannot reach a conclusion regarding the degree of conservatism in the present analysis methodology.

Response to RAI 7 comment

In the Supplement 2 to BISON Topical Report, WCAP-16606-P on page 41, the basic conservative approach is described. [

]a,c

[

]a, c This is very conservative with respect to containment loads because more energy will be generated in the core if the shutdown is delayed.

An additional conservative factor is introduced to account for the effects not modeled in BISON like [ ]a, c Typically a value of [ ]a, c is used, but the number is plant specific. The base of this value is found in the plant ATWS analysis of record, SAR and/or Technical Specification Basis that was originally used to demonstrate the containment loads at boron shutdown during an ATWS. The value should be provided by the customer as a part of the data transfer in the case that it is not explicitly given in the SAR or the Technical Specification Basis of the plant. This value is required to determine the boron concentration in the SLCS tank(s) solution that is required to comply with the pertinent requirements in 10CFR50 and is therefore available in the ATWS analysis of record. In the application example in WCAP-16606-P an example [

]a, c, and results in a "double conservatism" in the proposed methodology.

In the BISON code, all bypasses including fuel assembly internal bypasses (water-cross, water rod etc) are modeled as [

]a, c (see equation 4.7, p. 12 in WCAP-16606-P) even though the concentration in the water is constant. The counteracting effect on the power due to the increase in the absolute value of the void coefficient (see description on how this impacts k_{eff} on page 218 in the original topical, Reference 1) [ ]a, c This adds even more conservatism to the shutdown calculation. Bypass voiding occurs early in the transient if the initiating event is a PRFO like the application example provided in section 6 of WCAP-16606-P. During the borating phase voiding occurs frequently when the safety valve opens since the water in the core bypass is saturated due to the reversed flow that follows the recirculation pump trip. [

]a, c

To demonstrate the impact of the multiplier Eboron (boron efficiency, E_{bc}) on the containment load until the time all boron is injected, in this case 1300 seconds, three different cases with different multipliers were simulated. [ ]a, c

[ ]a,b,c

The integrated containment load for the different Eboron values are given in the table below.

[ ]a,b,c

[ ]a,c

Consider the following figure from WCAP-16606-P:

[ ]a,c

[ ]a,c

[

]a,c

This best estimate case is compared to a reference case calculated according to the proposed methodology.

a,b,c

[

]

A zoom in from 250 to 650 seconds is shown below:

a,b,c

[

]

[

]a, c

The term "core flow" in the responses as well as the graphs of "core flow" shown in WCAP-16606-P should say "core inlet flow", i.e. the flow entering the core from the lower plenum through the core support plate inlet orifices. Bypass flow enters the core downstream this flow in the BISON model. So the response to RAI-7 is valid with the above clarification on the flow.

The RPV peak pressure is not affected by the boron modeling. The RPV peak pressure is determined without boron injection credited as exemplified in the section describing "phase 1" in WCAP-16606-P (pages 28-30).

Reference:

1. RPA 90-90-P-A, Rev. 0, "BISON - A One Dimensional Dynamic Analysis Code for Boiling Water Reactors," December 1991.

Comment regarding RAI 8

The time delay before applying the uniform boron concentration is based on a transport time from the injection sparger to the point where boron would enter the active region of the core. For injection above the top of active fuel (TAF) this is most likely conservative due to conservatively adding the transport through the core bypass. However, for lower head injection this is non-conservative and a time delay should consider the time it takes for boron to breach the active region. The staff would accept an increase in the time delay based on the core average liquid velocity and active length (approximately 2 - 5 seconds).

Response to RAI 8 comment

What is applied as delay when injection is BAF is [
]a, c as stated on page 37 in WCAP 16606-P. This is naturally conservative as the comment says.

Comment regarding RAI 9

The staff intends to impose a condition on the approval of WCAP-16606-P, limiting the applicability of the BISON code only for suppression pool load, containment response, core coolability assessment, and peak pressure for pressurization ATWS events. A caveat will be added to the approval that licensees referencing the method must indicate compliance with generic longer term stability (LTS) solutions and EPGs consistent with mitigation of instabilities under non-isolation ATWS events.

Response to RAI 9 comment

Westinghouse acknowledges the applicability limit as it applies to methods contained in WCAP-16606-P BISON Supplement 2. Westinghouse does not envision using BISON to address abovementioned ATWS instabilities, and does not believe the related caveat applies.