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LTR-NRC-10-47
August 11, 2010

Subject: Response to the NRC's Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-16865-P, Rev. 1, "Westinghouse BWR ECCS Evaluation Model Updates: Supplement 4 to Code Description, Qualification and Application" (Proprietary/Non-Proprietary)

Enclosed are copies of the Proprietary and Non-Proprietary versions of the responses to the NRC's Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-16865-P, Rev. 1, "Westinghouse BWR ECCS Evaluation Model Updates: Supplement 4 Code Description, Qualification and Application."

Also enclosed is:
1. One (1) copy of the Application for Withholding, AW-10-2896 (Non-Proprietary) with Proprietary Information Notice and Copyright 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 Proprietary Information 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-10-2896 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

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

Enclosures
cc: E. Lenning, NRR

T007
NRR

Add: E Lenning
to ERIDS

LTR-NRC-10-47
August 11, 2010

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Reference: See attached EP-304-2

The contents of the transmittal letter have been verified to be complete and correct. In addition Three Pass Verification (3PV) was used to verify this document.

Verified by Mike Riggs
Fuel Engineering Licensing

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AW-10-2896
August 11, 2010

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-10-47 P-Enclosure, "Response to the NRC's Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-16865-P, Rev. 1 'Westinghouse BWR ECCS Evaluation Model Updates: Supplement 4 to Code Description, Qualification and Application'" (Proprietary)

Reference: Letter from J. A. Gresham to Document Control Desk, LTR-NRC-10-47, dated August 11, 2010

The Application for Withholding Proprietary Information from Public Disclosure 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-10-2896 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-10-2795 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: E. Lenning, NRR

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 11th day of August 2010.

Notary Public

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

(1) I am Manager, 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 Proprietary Information from Public Disclosure accompanying this Affidavit.

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

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

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

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

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

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

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

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

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

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

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

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

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

(b) It is information 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 in LTR-NRC-10-47 P-Enclosure, "Response to the NRC's Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-16865-P, Rev. 1 'Westinghouse BWR ECCS Evaluation Model Updates: Supplement 4 to Code Description, Qualification and Application'" (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-10-47) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse Electric Company includes responses to NRC requests for additional information.

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

(a) Obtain NRC approval for the Westinghouse BWR ECCS Evaluation Model Updates.

(b) Allow Westinghouse to accurately model and analyze the ECCS in BWRs.

Further this information has substantial commercial value as follows:

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

(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.

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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Response to the NRC's Request for Additional Information RE: Westinghouse Electric Company Topical Report WCAP-16865-P, Rev. 1, "Westinghouse BWR ECCS Evaluation Model Updates: Supplement 4 to Code Description, Qualification and Application" (Non-Proprietary)

August 2010

Westinghouse Electric Company
P.O. Box 355
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1. Describe the heat transfer equations for the average and hot channel wall temperature calculation for the period during lower plenum flashing up to and including the period of core spray rated flow:
   a. Define each term in sufficient detail and discuss how those terms are obtained.

      Response

      The GOBLIN heat transfer model is described in Section 3.5 of Reference 1-1. Figure 1-1 shows the post-dryout flow regime map used in GOBLIN. During lower plenum flashing up to and including the period of core spray rated flow, the flow regime of interest shown in Figure 1-1 is the high void fraction regime [ ][a,c] in which the model makes use of the following three heat transfer correlations:

      i) For turbulent forced convection, the Dittus-Boelter correlation is used. The Dittus-Boelter correlation and how it is applied in the GOBLIN code is described in subsection "Turbulent Forced Convection Regime" of Section 3.5.2 of Reference 1-1.
      ii) For laminar forced convection, the Seider-Tate correlation is used. The Seider-Tate correlation and how it is applied in the GOBLIN code is described in subsection "Laminar Forced Convection Region" of Section 3.5.2 of Reference 1-1.
      iii) For turbulent and laminar natural convection, the Jakob correlation is used. The Jakob correlation is described in detail in Subsection "Laminar and Turbulent Natural Convection Regime" of Section 3.5.2 of Reference 1-1.

   b. Discuss what information from the average channel calculations feeds the hot channel calculation. Discuss any coupling.

      Response

      In the GOBLIN calculation, the average and hot channels are coupled by the same hydraulic nodes that the fuel assemblies are connected to at both ends - namely the upper most node of the lower plenum region, the bottom node of the core bypass region and the upper plenum hydraulic node to which top of the fuel assemblies is connected. Because the GOBLIN average channel component represents all but one of the fuel assemblies, the thermal hydraulic states of the connecting nodes that provide the common boundary conditions to both channels are determined predominately by the average channel calculations. As a result, the hot channel calculation can be considered as "driven" by the average channel calculation.

   c. Provide this information for both the currently approved model and the proposed model.

      Response

      There is no change regarding the channel calculation coupling.

d. Discuss how the core spray flow is accounted for both before and after it reaches rated flow. Before the core spray reaches rated flow, will the core spray flow increase the pressure drop across the core and therefore decrease the steam flow rate through the core? How is this decrease carried through to the hot channel?

<u>Response</u>

In GOBLIN, the core spray before and after it reaches rated flow is added to the upper plenum hydraulic node in which the core spray nozzles are located. During the blowdown phase, condensation of steam by the subcooled spray water has more impact on the core heat transfer than the increase in core pressure drop caused by the presence of core spray water droplets. As explained in the response to part (b) of RAI-1, the hot channel boundary conditions are predominately determined by the average channel calculation and a change in plenum to plenum pressure drop will be seen by both average and hot channels.

e. The current model uses one definition for the end of lower plenum flashing. Demonstrate that the proposed model for the end of lower plenum flashing will not over estimate the heat transfer to the hot channel.

<u>Response</u>

With the proposed change in the definition of end of lower plenum flashing, during the blowdown phase, the GOBLIN convective heat transfer coefficient will be used by CHACHA until the rated spray flow condition is reached. To eliminate any non-conservatism in the GOBLIN convective heat transfer calculation due to the presence of core spray water in the hot assembly, Westinghouse is proposing to impose another constraint – [

]^{a,c}

a,c

Figure 1-1 GOBLIN Post-Dryout Heat Transfer Flow Regime Map

Reference

1-1 "Boiling Water Reactor Emergency Core Cooling System Evaluation Model: Code Description and Qualification," Westinghouse Report RPB 90-93-P-A (Proprietary) , RPB 90-91-NP-A (Non-Proprietary), October 1991.

2. The spray cooling heat transfer coefficients used, once core spray reaches rated flow, are based on data and are considered conservative, but only by 15%. Because spray cooling injection starts some seconds before it reaches rated flow, a gradual transition would be expected where the heat transfer coefficient has a gradual change to meet the spray cooling heat transfer coefficient values which are based on test data. However, the CHACHA-3C calculation does not show a gradual change, but a step change by a factor of 10. Justify CHACHA-3C's calculation of the heat transfer coefficients and explain why CHACHA-3C over predicts the spray cooling heat transfer test data.

Response

The Appendix K core spray (CS) heat transfer coefficients (HTCs) were derived from single bundle separate effect experiments, which were performed at constant pressures.

The Appendix K CS HTCs therefore do not include any additional steam cooling due to steam updraft from the flashing of water in the lower plenum and the spray droplets within the fuel assembly during the blowdown phase. At the time when rated core spray flow is reached, the difference between GOBLIN convective HTC and the Appendix K core spray HTC depends mainly on the reactor pressure vessel depressurization rate and the amount of core spray droplets in the hot assembly.

To eliminate the uncertainty in the hot assembly heat transfer calculation due to the flashing of core spray droplets, Westinghouse proposes to conservatively [

]^{a,c}.

The PCT sensitivity runs using the BWR/3 LOCA DBA case for a constant peaking factor (FRAD) of 1.65 described in Section 6.1.1 of WCAP-16865 Rev. 1 have been recalculated with the proposed change in the definition of end of lower plenum flashing and with [ ]^{a,c}. Figures 6-1 and 6-2 of WCAP-16865 Rev.1 showing the PCT and CHACHA HTC have been regenerated and are shown herein as Figures 2-1 and 2-2, respectively.

Because the Appendix K core spray HTCs are correlated with saturation steam temperature, the CHACHA HTC shown in Figure 2-2 is also coolant saturation temperature based to make the HTC comparison at the spray flow transition time more meaningful.

Table 6-1 of WCAP-16865 Rev. 1 summarizing the impact on PCT of the above case is replaced by Table 2-1 herein.

[ ] a,c

The sensitivity study performed for a constant PCT of 2150°F at the limiting lattice as documented in Section 6.1.2 of WCAP-16865 Rev.1 has also been revised with the proposed change in the definition of lower plenum flashing and with [ ]^{a,c} Table 6-2 of WCAP-16865 Rev. 1 summarizing the impact on limiting lattice relative power is replaced by Table 2-2 herein.

Table 2.2 Impact on Limiting Lattice Relative Power (PCT = 2150°F)

[ ] a,c

a,c

Figure 2-1 PCT comparison for End of LPF Time and Zero Hot Assembly Core Spray Sensitivity Runs (FRAD = 1.65)

a,c

Figure 2-2 HTC comparison for End of LPF Time and Zero Hot Assembly Core Spray Sensitivity Runs (FRAD = 1.65)

3. From Figure 3-6 of the topical report, it seems that delaying the time it takes for core spray to reach rated flow (making the time frame longer between core spray initiation and rated flow) will allow higher heat transfer and a lower Peak Cladding Temperature. Provide a sensitivity study which demonstrates this is not the case. If this is the case and having core spray reach rated flow earlier results in higher PCTs, justify the core spray time delay.

Response

A sensitivity study was performed using the BWR/3 limiting DBA to investigate the impact on PCT when the time for the core spray (CS) to reach rated flow condition is extended. The base case made use of the extended end of lower plenum time and [ ]^{a,c}. In the perturbed case, the CS flow during the transition time to reach rated condition was artificially reduced. The resulting convective heat transfer coefficients (HTCs) and peak cladding temperature (PCT) are compared with the base case results.

Figure 3-1 compares the CS flow and total system water mass for the two cases. It shows that the CS initiation time is kept the same (at about 31 seconds). However, for the perturbed case, the CS flow during the spray flow transition period is reduced. As a result, the time to reach the rated CS condition is extended by about 4 seconds (from 45 seconds to 49 seconds).

The total system inventory comparison in Figure 3-1 shows that by reducing the CS flow, it takes longer to reflood the reactor pressure vessel and the refill time is delayed by approximately 2 seconds.

Figure 3-2 shows the comparison of dome pressure and steam inlet flow into the hot assembly during the core spray transition time period. It shows that the depressurization rate is less for the reduced CS case and this can be attributed to a lesser steam condensation in the upper plenum due to reduced CS flow. Slower depressurization causes a lower rate of lower plenum flashing. As a result, the steam inlet flow and steam cooling in the hot assembly is lower for the perturbed case.

Figure 3-3 compares the convective HTC and PCT. The HTC comparison indicates that from about 31 seconds (time of CS initiation) to 45 seconds (time when the rated CS flow is reached in the base case), the HTC for the perturbed case is lower because of the reduced steam inlet flow. However, the HTC for the perturbed case is higher than the base case during the prolonged time in reaching rated CS flow condition (from 45 to 49 seconds).

The HTC from both cases are the same during the CS cooling period. However, at approximately 180 seconds the HTC for the perturbed case is lower than the base case because the recovery time is delayed by approximately 2 seconds.

Figure 3-4 compares the PCTs for the two cases. [ ]^{a,c} Comparison of rod temperature shows that the difference in HTC during the transition period has almost no effect on PCT. The increase in PCT can be attributed mainly due to the delay in reflooding time.

Based on this sensitivity study, it is concluded that there is no advantage in extending the time to reach the rated CS.

a,c

Figure 3-1 Comparison of Core Spray Flow and System Water Mass

a,c

Figure 3-2 Comparison of Dome Pressure and Hot Assembly Steam Inlet Flow

a,c

Figure 3-3 Comparison of CHACHA Convective Heat Transfer Coefficient

a,c

Figure 3-4 Comparison of Peak Cladding Temperature

4. Westinghouse's new definition of the end of lower plenum flashing is defined as "the time after initiation of lower plenum flashing when either (1) water inventory in the lower plenum vanishes, OR (2), depressurization in the lower plenum stops. Flashing of initially subcooled lower plenum water beings after the lower plenum pressure drops to the saturation pressure in the region. If the water in the lower plenum region becomes subcooled again, will lower plenum flashing cease? If so, should this be added to the definition of the end of lower plenum flashing?

   Response

   Westinghouse agrees that lower plenum flashing will cease when the water in the lower plenum region becomes subcooled again.

   The end of lower plenum flashing definition will be revised as the time after initiation of lower plenum flashing when either

   (1) Water inventory in the lower plenum vanishes, OR

   (2) Depressurization in the lower plenum stops, OR

   (3) When the water in the lower plenum region becomes subcooled again.

5. Provide a graphic which gives the location of the Side Entry Orifice (SEO).

   Response

   As shown in Figure 6-13 of Lahey and Moody, "The Thermal-Hydraulics of a Boiling Water Nuclear Reactor" (May 1993), the side entry orifice is located at opening #2.

6. Provide ROSA-III data for Lower Plenum Water Temperature and compare to the predictions of GOBLIN presented in figure 5-19 of the topical.

   Response

   Figure 5-19 of the topical has been updated to include the ROSA-III measured data of lower plenum water temperature. The updated plot is shown in Figure 6-1 herein.

a,c

Figure 6-1 GOBLIN ROSA-III Lower Plenum Water Temperature Comparison

7. The faster depressurization rate in GOBLIN is due to break flow modeling. For safety analysis, the Moody model is prescribed and this would lead to an even faster depressurization than that predicted by the HEM model when comparing to the ROSA-III test. Provide discussion addressing this faster depressurization rate and associated increased steam flow rate, specifically verifying that that increased heat transfer due to the increased steam flow rate would still result in conservative calculation.

<u>Response</u>

To study the impact of GOBLIN break flow model on the fuel rod heat transfer, the BWR/3 limiting DBA case is repeated with the Moody critical flow model replaced by the homogeneous equilibrium model (HEM), which is closer to a best estimate of the actual break flow for a given break area.

Figure 7-1 compares the GOBLIN break flows, dome pressures and depressurization rates between the two break flow options during the initial blowdown phase of the LOCA transient. It can be seen that the break flows are higher with the Moody model until around 20 seconds and then the reverse is true for the rest of the blowdown phase.

The vessel pressure comparison shows that the dome pressure is lower with the Moody model option for the entire blowdown period due to higher inventory loss in the first 20 seconds. However, the rate of depressurization is not always higher with the Moody model. After approximately 25 seconds, the depressurization rate from the HEM model becomes consistently higher.

Figure 7-2 compares the vapor inlet flow and mid-plane void fraction of the hot assembly. The vapor inlet flow comparison shows that approximately 8 seconds after the break, steam from the lower plenum starts to flow into the hot assembly when the initially subcooled water in the lower plenum reaches saturation as the system pressure drops. With the Moody model, lower plenum flashing occurs at approximately 8 seconds, about 1 second sooner than the HEM predicts. The initial surge of steam inlet flow peaks sooner with the Moody model and at approximately 17 seconds the steam inlet flow is higher with the HEM. The lower steam inlet flow rate with Moody is consistent with the differences in depressurization rate predicted by the two models.

The hot assembly mid-plane void fraction plot in Figure 7-2 shows that Moody predicts an earlier water depletion of hot assembly due to higher critical flow. As a result, the initial fuel rod heat up happens sooner with the Moody model (See Figure 7-4).

Figure 7-3 compares the GOBLIN convective heat transfer coefficient (HTC) at the mid-plane location of the hot assembly during the blowdown phase. It shows that hot assembly HTC with Moody decreases sooner (approximately 18 seconds) than that of HEM due to a faster initial inventory loss. The HTC remains lower for the Moody due to less steam cooling from the lower depressurization rate.

Figure 7-4 shows the peak power rod temperature at the mid-plane predicted by GOBLIN for the two critical flow options. The results indicate that using the Moody model yields a higher cladding temperature.

Based on this sensitivity study, it is concluded that from the core heat transfer perspective, the Appendix K prescribed Moody critical flow is more conservative with regard to cooling from lower plenum flashing than the realistic HEM.

a,c

Figure 7-1 Comparison of Break Flows, Dome Pressure and Dome Pressurization Rate

a,c

Figure 7-2 Comparison of Hot Assembly Vapor Inlet Flow and Mid-plane Void Fraction

a,c

Figure 7-3 Comparison of HTC at Mid-Plane of Hot Assembly

a,c

Figure 7-4 Comparison of GOBLIN Cladding Temperature of Peak Power Rod at Mid-Plane

8. By changing the definition of the end of lower plenum flashing, the proposed Westinghouse model is much more sensitive to the flashing model and the steam cooling heat transfer model. It seems that these models may have had little impact on the core heat transfer with the previous definition of 'end of lower plenum flashing' and will have a much greater impact with the change in the definition of 'end of lower plenum flashing'. Demonstrate that these models have been adequately validated and demonstrate that any model sensitivities (such as sensitivities to rapid changes in pressure) have been accounted for such that under all anticipated uses the models will result in a conservative estimate of the PCT.

Response

GOBLIN has been qualified using test data collected from BWR integral system test facilities that simulate postulated BWR LOCA events. Specifically, benchmarking of GOBLIN using ROSA-III Run926 is documented in WCAP-16865-P and qualification of GOBLIN using TLTA and FIX-II test data can be found in Sections 6.2 and 6.3 of Reference 8-1. The BWR LOCA blowdown phase and steam cooling due to lower plenum flashing are included in these benchmarking cases.

Two additional GOBLIN ROSA runs have been performed by varying the break flow rates to study the sensitivity of GOBLIN predicted PCT with respect to the depressurization rate. Break flow rate is chosen as the variable parameter because it has the largest impact on the system depressurization rate. In the first case, a multiplier of 1.1 is applied to the nominal Homogeneous Equilibrium Model (HEM), and in the second case, the HEM is replaced by the Appendix K required Moody critical flow model.

The first plot in Figure 8-1 compares the system pressures from the two perturbed cases with the nominal GOBLIN result and the ROSA test data. It shows that the GOBLIN depressurization rate is highest for the Moody option followed by the 110% and 100% nominal break flow cases.

The clad temperatures at the peak power location of the corresponding runs are shown in the second plot of Figure 8-1. It shows that, with the nominal HEM break flow model, GOBLIN conservatively over predicts the rod temperature by [ ][a,c]. Another [ ][a,c] of conservatism is added with the usage of the Moody model. Because the Moody model is used in the Westinghouse BWR LOCA methodology, it can be concluded that using the proposed method will result in a conservative estimate of the PCT during the blowdown phase.

a,c

Figure 8-1. Break Size / Depressurization Rate Sensitivity – GOBLIN ROSA PCT

<u>Reference</u>

8-1 "Boiling Water Reactor Emergency Core Cooling System Evaluation Model: Code Description and Qualification," Westinghouse Report RPB 90-93-P-A (Proprietary), RPB 90-93-NP-A (Non-Proprietary), October 1991.

9. What events (accidents/transients) will see the largest impact from the change in the definition of 'end of lower plenum flashing' and what is the largest impact expected in terms of PCT?

Response

To identify the largest impact from the change in the definition of 'end of lower plenum flashing', a typical limiting BWR/3 recirculation pump line break spectrum is performed using the current and proposed methodologies.

For the double-ended guillotine breaks at the recirculation pump suction location, the limiting single failure of Low Pressure Coolant Injection (LPCI) injection valve is assumed and the available Emergency Core Cooling Systems (ECCS) are the Automatic Depressurization System (ADS), High Pressure Coolant Injection (HPCI) pump and 2 Lower Pressure Core Spray (LPCS) pumps. The break sizes analyzed are 100%, 80%, 60%, and 27.7%, which corresponds to a 1.0 ft^2 break. For these large break cases ADS and HPCI are never activated due to rapid system depressurization.

For the longitudinal split breaks at the recirculation pump discharge location, the limiting single failure of HPCI is assumed and the available ECCS are ADS, 2LPCS, and 4LPCI. The break sizes analyzed are 0.15, 0.10, and 0.05 ft^2.

All cases are analyzed at a Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) value of 8.55 kW/ft and the results for the large double-ended breaks and small split breaks are tabulated in Tables 9-1 and 9-2, respectively. The composite results are also depicted in Figure 9-1.

Figure 9-1 shows the trend of PCT with respect to the break size remains essentially the same with both methods. With the proposed method, the highest Peak Clad Temperature (PCT) is [ ]^{a,c} (at 100% double ended break) as compared to[ ]^{a,c} (at 80% of full break size) using the current method which is an overall decrease of [ ]^{a,c} in PCT.

The largest impact on PCT, however, occurs at the non-limiting break size of 0.1 ft^2 in which the clad temperature is reduced by [ ]^{a,c}. For this particular case, after ADS is activated, the core is uncovered for the longest duration amongst the small break cases analyzed. With the proposed methodology, the conservative adiabatic heat up despite the continuous depressurization from actuation of ADS is replaced by steam cooling, resulting in the biggest improvement in PCT.

Table 9-1 BWR/3 Large Recirculation Pump Suction Line Breaks

[ ] a,c

Table 9-2 BWR/3 Small Recirculation Pump Discharge Line Breaks

[ ] a,c

a,c

Figure 9-1 GOBLIN Recirculation Line Break Spectrum with Current and Proposed Methods

10. Provide a plot of Figure 5-28 (Comparison of temperature at the plane of peak power) with the ROSA data, as well as GOBLIN with both the currently approved and proposed definitions of 'end of lower plenum flashing'.

<u>Response</u>

The GOBLIN calculated clad temperatures at the plane of peak power using the current and the proposed methodologies are added to Figure 5-28 of the submitted WCAP and the results are shown in Figure 10-1 herein.

To preserve the accurate system response predicted by GOBLIN, the Appendix K requirements of using a higher level of decay heat and the Moody critical flow model were not applied in the sensitivity runs using the current and proposed LOCA methodologies.

Figure 10-1 compares the GOBLIN calculated temperatures of the peak power rod at the peak power plane with ROSA-III test data. It shows that, although the GOBLIN predicted peak clad temperature (PCT) using the proposed methodology is lower than the current methodology value by [ ]^{a,c}; it is still higher than the ROSA test data by [ ]^{a,c}.

a,c

Figure 10-1 Comparison of Temperature of Peak Power Rod of High Power Bundle at 3.08 ft (Peak Power Plane)

11. In the ROSA test, GOBLIN is able to match the heat ups during the period of lower plenum flashing which indicates that the heat transfer coefficients at this time are a best estimate of the actual heat transfer. Is the time in which lower plenum flashing cools the core typical of transients and accidents for BWRs, or would the steam cooling and stem generation play a larger role in determining the clad PCT in other analysis? In other words, does the ROSA test provide a limiting scenario to determine the impacts of the steam cooling and steam generation models? What assurances are there that use of steam cooling and steam generation models in other transients or accidents will not over predict the heat transferred from the fuel and result in a non-conservative PCT calculation.

Response

The main objective of the ROSA-III LOCA test program is to produce the significant thermal hydraulic phenomena that would occur in postulated BWR LOCA events. The test facility is volumetrically scaled to accurately capture the timing and magnitude of the key phenomena such as the onset of lower plenum flashing and the subsequent steam cooling of the core during the initial blowdown phase of a large recirculation line break.

Typical BWR recirculation line break spectrum calculations, such as the one presented in the response to RAI-9, show that the largest double-ended guillotine breaks yield the highest PCTs. Assessing GOBLIN with ROSA Run926, which simulates a 100% double-ended guillotine break at the pump suction location, demonstrates the capability of GOBLIN to accurately predict the steam cooling during the initial blowdown phase for the limiting scenario.

As shown in the response to RAI-9 herein, using the steam cooling and steam generation models as proposed in this LTR has the largest impact on the non-limiting small break LOCAs. The previous approach, which did not credit the available steam cooling, resulted in an artificially skewed break spectrum. The proposed approach more clearly identifies the limiting break to be the large breaks, as illustrated in Figure 9-1. This assures that the condition leading to the limiting PCT is identified.

References

1. Ebeling-Koning, D.B, et al., "Westinghouse Boiling Water Reactor Emergency Core Cooling System Evaluation Model: Code Description and Qualification", WCAP-11284-P-A Addendum 1, RPB 90-93-P-A, October 30, 1989 (ADAMS Accession No. ML070890510 (Non-Proprietary Available)).