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January 16, 2014
U7-C-NINA-NRC-140001

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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South Texas Project
Units 3 and 4
Docket No. PROJ0772
Supplemental Response to Request for Additional Information

Reference: Letter from Michael Eudy to Scott Head, Request For Additional Information RE: South Texas Project Nuclear Operating Company Topical Report WCAP-17202-P, "Supplement 4 to BISON Topical Report 90-90-A" (TAC No. RG0028), June 3, 2013 (ML13142A082)

Attached is a supplemental response to several previously submitted RAI responses on the BISON Topical Report, WCAP-17202-P. This response removes the steam condensation model from consideration by the NRC as part of BISON Topical Report review. As a result of this decision, this response supersedes the following previously submitted responses:

RAI 15.00.02-32
RAI 15.00.02-32S01 through S06
RAI 15.00.02-34
RAI 15.00.02-34S01
RAI 15.00.02-35
RAI 15.00.02-35S01 and S02
RAI 15.00.02-38
RAI 15.00.02-38S01

The Attachment contains the response that supersedes these RAI question responses.

There are no commitments in this letter.

TO10
NRD

STI 33809229

If you have any questions, please contact Scott Head at (979) 316-3011, or Bill Mookhoek at (979) 316-3014.

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

Executed on 1/16/14

Scott Head
Manager, Regulatory Affairs
NINA STP Units 3 & 4

jet

Attachment:
RAI 15.00.02-32, 34, 35, 38

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

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15.00.02-32:

Section 3.5.1 of WCAP-17202 summarizes observations of the current BISON simulation of the Hamaoka-5 start-up tests, but does not reference the supporting documentation.

a. In order to appreciate the overall improvements in the BISON model predictions after incorporation of the new steam dome water surface condensation model, provide the reference where the BISON calculations of Hamaoka-5 start-up tests are documented or provide the results of comparison of the original BISON code for the Hamaoka-5 start-up tests (pressure in dome, water level, and water subcooling).

b. Explain whether the third bullet is an experimental observation or a BISON prediction.

RAI 15.00.02-32S01:

In response to Part (a) of RAI-15.00.02-32, the applicant stated that the BISON calculations for the Hamaoka-5 start-up tests are available in WCAP-17202-P. However, WCAP-17202-P only provides comparisons of the Hamaoka-5 start-up test data (LRWBP & MSIVC) against the updated BISON code. The RAI requested the predictions of the original BISON code for Hamakoka-5 startup test data. It would be helpful if the results of approved (original) and the updated BISON codes and the corresponding test data for dome pressure, water level, and water subcooling (if available) are shown on the same graph.

Furthermore, please show the results for the LRWBP transient up to 150 seconds as the effect of surface condensation is dominant in the period of 100 to 145 seconds into the transient. Furthermore, WCAP-17202-P observation that the approved BISON code over-predicted the dome water level due to absence of water surface condensation model seems contradictory. In absence of condensation model, the dome level is expected to be under-predicted. The applicant also reports that the prediction of the dome water level improved after introduction of the surface condensation model. However, this assertion is not supported by the information presented in WCAP-17202-P and in the RAI response. The information requested in this follow-up RAI is expected to address these issues.

Figure 3-19 of WCAP-17202-P indicates that for the LRWBP transient, the dome pressure start to decrease after 100 seconds. Therefore, the surface condensation is also expected to be effective after 100 seconds into the transient. However, the comparisons of the updated BISON and POLCA-T against the LRWBP test data are shown only up to 100 and 80 seconds, respectively. Therefore, please show the test data and code prediction up to 150 seconds for the LRWBP transient.

RAI 15.00.02-32S02:

The Hamaoka-5 LRWBP experiment data measured between 60 to 100seconds is used for the development of the correlation/model (see Table 1 of the response to RAI-15.00.02-32). However, as discussed in follow-up RAI-15.00.02-32S01, the substantial reduction in dome pressure occurs only after 100 seconds. One would expect that condensation is dominant in the period of 100 to 145 seconds (when the dome pressure is actually decreasing), and the experimental measurement up to 150 seconds should be used for development of the correlation. Please clarify the basis for considering the data up to only 100 seconds for the model development even though condensation is expected to dominant up to 150 seconds.

RAI 15.00.02-32S03:

The BISON code nodalization shown in RPA-90-90-P-A (Figure 3-2) indicates that the dome is represented by a single node/control volume (i.e. no subdivisions). With this nodalization, it is not possible to calculate the water surface subcooling in the dome.

However, WCAP-17202-P and the RAI response consistently state that the condensation rate is correlated to the water surface subcooling. Therefore, please clarify the approach used to calculate the water surface subcooling.

RAI 15.00.02-32S04:

The change in dome water level (or steam volume) due to surface condensation is neglected for the development of the water surface condensation model. However, the RAI response and WCAP-17202-P frequently assert that the updated BISON code provides improved prediction of the dome water level. This assertion cannot be supported by the information provided in WCAP-17202-P and the RAI response. The data presented in Table 1 of the RAI response indicates that total amount of condensate (424 kg) correspond to the dome water level of approximately 2.6 cm. An error in measurement of water level is +/- 1.6 cm (per the response to RAI-15.00.02-36). Since the error in water level measurement is of the same order of magnitude as the total change in dome water level that is expected due to the surface condensation, the assertion that the inclusion of the surface condensation model results in improved prediction of water level cannot be supported. Please explain how the model was considered to improve the dome water level prediction given the uncertainty in the plant water level measurement.

RAI 15.00.02-32S05:

The response to RAI-15.00.02-32 notes that the data presented in Table 1 of the response is used for the development water surface condensation model. Furthermore, the response to RAI-15.00.02-35 states that the same data has been plotted in Figure 3-18 of the LTR, which shows the model curve derived from the data. However, the data presented in Table 1 of the RAI response is not consistent with Figure 3-18. Furthermore, the condensation rate values presented in the last column of Table 1 cannot be verified. The unit of the condensation rate shown for this column is also questionable. Please clarify these discrepancies in the test data.

RAI 15.00.02-32S06:

The RAI response indicates that the boiling type correlation is used to arrive at the final form of the surface condensation model. A heat flux due to condensation is assumed directly proportional to the square of the water surface subcooling. As a result the condensation rate in the new model is also directly proportional to the square of the water surface subcooling. As explained below the reviewers find this approach to be fundamentally incorrect.

Heat flux due to condensation of pure steam at the surface of subcooled water is expected to be directly proportional to the temperature gradient across the thermal boundary layer in the liquid phase. With pure steam present in the dome, the temperature at the dome water surface is expected to remain at saturation condition corresponding to the dome pressure and the surface condensation is expected to be due to transfer of heat (i.e. latent heat of phase change) to the bulk liquid (which is subcooled) across the liquid phase forming the interface between the vapor and the subcooled pool thermal boundary layer. Consequently, the condensation heat transfer coefficient would be directly proportional to the thermal conductivity of water and inversely proportional to the thickness of the thermal boundary layer. The thickness of thermal boundary layer would depend on the flow regime (laminar or turbulent). In case of the laminar regime, the thickness of the thermal boundary layer would increase with time leading to a decrease in the condensation rate (i.e. heating of the water near the surface). For turbulent conditions, the thickness of boundary layer is expected to be small due to extensive eddy mixing leading to a higher condensation rate. In summary, the condensation rate is expected to be directly proportional to the water subcooling and not to the square of water subcooling as assumed in the model. A review of other well established liquid surface condensation models such as Nusselt condensation on the surface of laminar liquid film also shows that the condensation rate is linear and not quadratic in temperature gradient. Use of the exponent of 2 for temperature gradient may lead to over-estimation of condensation rate if the model/correlation is applied outside the range of test data. Please justify the rationale behind considering that the surface condensation rate is directly proportional to the square of the water surface subcooling.

15.00.02-34:

Section 3.5.2 of WCAP-17202 states that "the applied model is a second degree polynomial versus surface subcooling (♦Tsurf)," which is presented in proprietary Equation 3-49.

a. Please provide the physical basis for the selection of the polynomial dependence used in the model. Comment on the generality of the purely empirical model for steam dome water surface condensation when applied to all possible ABWR related transient scenarios.

b. Discuss the physical significance of each model parameter in Equation 3-49.

c. Address the implications of having a finite amount of condensation for zero subcooling.

d. Surface condensation is due to transfer of heat from vapors to subcooled liquid surface and the condensation rate is equivalent to the heat transfer rate divided by latent heat. Since the latent heat is function of pressure, the surface condensation rate is also pressure dependent. Discuss the pressure dependence of each model parameter in Equation 3-49.

e. The interfacial condensation heat transfer coefficient between vapor space and the subcooled liquid surface is affected by the flow conditions (e.g., laminar, turbulent, natural convection, forced convection) in vapor and liquid phases. These flow conditions can vary during the transient, and can be very different for different type of transients. Discuss how the model captures dependence on flow conditions or the implications of not including it.

RAI 15.00.02-34S01:

In response to Part (e) of RAI-15.00.02-34, the applicant claims that the thermal boundary layer at the pool surface in dome for the Hamaoka-5 LRWBP startup test is thicker than for any other transient. Since the condensation model is developed based on the LRWBP test data, the applicant states the condensation model is expected to provide conservative results for other transients. Please explain the basis for this assumption.

In response to Part (e) of RAI-15.00.02-34, the applicant claims that the thermal boundary layer at the pool surface in dome for the Hamaoka-5 LRWBP startup test is thicker than for any other transient. Since the condensation model is developed based on the LRWBP test data, the applicant states the condensation model is expected to provide conservative results for other transients. Please explain the basis for this assumption.

15.00.02-35:

Proprietary Figure 3-18 of WCAP-17202 presents a verification of the fitting of the condensation model. The following information is required related to this figure:

a. Please provide the values of all model parameters from Equation 3-49 used to generate the "Model" curve.

b. Provide the experimental conditions (e.g., pressure, flow conditions, test section geometry etc.) for the experimental data presented in the figure. Is this separate effect test data, integral effects data or plant data? Please explain the method used to measure the rate of condensation in the experiment and the uncertainty in the measurement.

c. Address the discrepancy in units reported for condensation C in Equation 3-49 versus Figure 3-18, and reconcile it to the units on the right hand side of Equation 3-49.

d. The value used for CONDR in Figure 3-18 differs from the value used for CONDR in Section 3.5.5. Please add to Figure 3-18 the model prediction using the CONDR value from Section 3.5.5, which is stated to be the BISON default

RAI 15.00.02-35S01:

The condensation rate in Table 1 of the RAI response has units of kg/sK. This implies (based on the response to RAI 15.00.02-32) that the subcooling was also used in the determination of the condensation rate.

a. Although subcooling may not be directly measured, comparison of the liquid temperature measurement in the plant and its prediction by BISON can provide the uncertainty in prediction of subcooling. However, such an uncertainty does not appear to be considered. Please justify neglecting the uncertainty in the prediction of subcooling by BISON in the calculation of uncertainty in the condensation rate since the units are listed as kg/sK.

b. Please show the propagation of uncertainty from pressure and temperature to obtain the value for condensation rate.

RAI 15.00.02-35S02:

The reviewer is unable to reconcile the data shown in Figure 3-18 (and Figure 1 of the RAI response) with that tabulated in response to RAI 15.00.02-32. Please explain how the data points for the condensation and the subcooling in Figure 1 of the RAI response are connected to the data in response to RAI 15.00.02-32.

15.00.02-38:

In the comparison shown in Figure 4 in Appendix A of WCAP-17202, the BISON prediction using the surface condensation model levels off after 90 seconds, whereas the data shows a continuous decrease in the pressure. Furthermore, the water level is consistently over-predicted between 40 to 80 seconds. Please explain these apparent discrepancies in behavior.

RAI 15.00.02-38S01:

The reviewers find it noteworthy that system pressure information from the plant till 100 seconds was used in the development of the condensation rate model (as shown in response to RAI 15.00.02-32. The system pressure plant data should already include the probable reasons provided in the response for the difference between data and prediction.

In light of this, please explain why the differences in the system pressure beyond 90 seconds cannot be caused by deficiencies in the model.

RESPONSE to RAI 15.00.02-32, 15.00.02-34, 15.00.02-35 and 15.00.02-38:

Westinghouse withdraws the request for review and approval for the steam condensation model. The model is described in Section 3.5 of WCAP-17202-P Revision 0, pages 3-31 through 3-34. The model has been withdrawn as it provides very minor benefits and only affects long term results.

Westinghouse intends to treat the medium ranked phenomenon H5 (as presented in WCAP 17203-P) conservatively in future applications, by not including the steam condensation model in the BISON code.

The use of the steam condensation model reduces pressure in the longer term portions of transients and for that reason its removal is conservative. Because the steam condensation model is being withdrawn and will not be used, the RAIs 15.00.02-32, 15.00.02-34, 15.00.02-35, and 15.00.02-38 will not be responded to.

Without crediting the steam condensation model, Appendix A of WCAP-17202-P Revision 0 needs to be modified to not include impact of the steam condensation model. The following graphs in Appendix A will be changed in the approved version:

Figure 3 Generator load rejection test, main process parameters. The simulation time will be reduced to 60 seconds from 100 seconds.

Figure 4 Generator load rejection test, changes of pressure and level compared to initial level. The simulation time will be reduced to 60 seconds from 100 seconds.

Figure 7 All MSIV closure, main process parameters. The simulation time will be reduced to 60 seconds from 100 seconds.

Figure 8 All MSIV closure changes of pressure and level compared to initial level. The simulation time will be reduced to 60 seconds from 100 seconds.

Since the steam condensation model is only activated at about 60 seconds after scram, limiting the simulation time to 60 seconds is sufficient to not take credit for the steam condensation model. Removing this model will not affect the limiting results of the transient, only the long term response of the code. No other figures in the topical report need to be updated since the model is not used in any other plots.