ENCLOSURE 2

M210152

Revised Response to Request for Additional Information (eRAI) 9862 Question 06.02.01 01

Licensing Topical Report NEDC-33922P, Revision 0, BWRX-300 Containment Evaluation Method

Non-Proprietary Information

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]].

SRP-Review Section: 06.02.01 - Containment Functional Design Application Section:

06.02.01-01 (eRAI 9862) [Audit Issue 1]
Date of eRAI Issue: 08/05/2021

Requirement

General Design Criterion 50 – *Containment design basis*. Requires the reactor containment structure, including access openings, penetrations, and the containment heat removal system be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any loss-of-coolant accident (LOCA).

General Design Criterion 38 -- *Containment heat removal*. A system to remove heat from the reactor containment shall be provided. The system safety function shall be to reduce rapidly, consistent with the functioning of other associated systems, the containment pressure and temperature following any loss-of-coolant accident and maintain them at acceptably low levels.

General Design Criterion 16 -- *Containment design*. Reactor containment and associated systems shall be provided to establish an essentially leak-tight barrier against the uncontrolled release of radioactivity to the environment and to assure that the containment design conditions important to safety are not exceeded for as long as postulated accident conditions require.

Issue

Guided by the Standard Review Plan (SRP) Section 6.2.1 and the General Design Criteria (GDCs) 50, 38, and 16 of Appendix A to 10 CFR Part 50 relevant to the containment design basis, the staff is reviewing the applicant's analytical model and assumptions used in the GEH LTR NEDC-33922P, Revision 0, BWRX-300 Containment Evaluation (CE) Method. An important objective of this LTR review is to assess the conservativisms and non-conservatisms associated with the presented GOTHIC model, in order to determine whether the CE methodology would be acceptably conservative and physically meaningful with respect to the containment thermal-hydraulic response. The staff needs to ensure that the BWRX-300 CE methodology incorporates sufficient conservatism to analyze the short-term and long-term containment thermal hydraulics response to the limiting design basis events (DBEs) to offset the inherent methodology uncertainties. In this regard, the applicant is requested to provide the following additional information regarding the precedent-setting BWRX-300 containment nodalization approach used in the GOTHIC code.

Request

1. In the GEH LTR NEDC-33922P, a containment nodalization study is presented for the large steam line break (LBLOCA) event. [[

   ]]. However, LTR Figure 6-12 shows that a [[

]] for the LBLOCA base case. This demonstrates that [[ ]] result in more conservative results. In this backdrop, the applicant is requested to justify that the default [[ ]] choice is sufficiently conservative to bound the uncertainties in the LBLOCA containment analysis, or provide an upper bound on the non-conservatism inherent in finer nodalizations for conservative LBLOCA case.

The plots in Figures 6-26 and 6-27 show the [[ ]] for the conservative LBLOCA case, though they are not documented in the LTR as such. As they are among the most important parameters predicted by the CE methodology, the staff requests documenting the limiting PCP and maximum shell temperature values for the conservative case in the LTR as updated by the break location and break flow direction sensitivity studies requested in RAI 06.02.01-03. This information is needed by the staff to establish the overall conservatism in the containment evaluation (CE) methodology for LBLOCA.

2. The small break LOCA (SBLOCA) and LBLOCA are different DBEs that involve different phenomenological concerns. However, the staff noted that no containment nodalization study is presented in the LTR for the SBLOCA. As the break flow is [[ ]]. As shown by Figure 6-17, [[ ]]. LTR Figures 6-12 and 6-13 show [[ ]]. These phenomena are equally applicable to SBLOCA. With the complex SBLOCA phenomenology involving the novel PCCS design and Reactor Cavity pool heat-up in the later stage of transient, [[ ]].

   Therefore, the applicant is requested to provide information to confirm that the nodalization is adequate for SBLOCA, consistent with the information provided for LBLOCA. For this purpose, the staff requests GEH to provide similar justification for nodalization used in the limiting SBLOCA analysis up to 72 hours to demonstrate that the predicted limiting containment pressure and temperature responses remain conservative and insensitive to nodalization changes, and to quantify the conservatisms in the [[ ]]. The associated PCCS temperature plots (similar to LTR Figure 6-32), PCCS heat removal rate plots, and the containment steam volume fraction plots (similar to Figure 6-17) in the SBLOCA nodalization study should be included and discussed.

Revised GEH Response to NRC Question 06.02.01-01

1. The nodalization study is performed to demonstrate that the results are sufficiently converged as the node size is decreased. The purpose of nodalization is not to introduce additional conservatism, but to increase the accuracy by ensuring that the spatial gradients of the phenomena controlling the containment response are adequately resolved. Increasing the node size (i.e., coarser nodalization) will provide less accurate results but does not necessarily assure that those results will be conservative for all cases. The differences between the base case and the finer nodalization cases are approximately [[ ]], as shown in Figure 6-12 of the Licensing Topical Report (LTR). This can be compared to the difference between the base case and the conservative case shown in Figure 6-26 in Revision 1 of the LTR. The difference between the peak pressures for the base and conservative cases is approximately [[ ]]. This result shows that the additional resolution resulting from finer nodalization beyond the base case is much smaller than the conservatism introduced by biasing the inputs and modeling parameters, and the results using the base case nodalization are in the conservative direction.

2. A nodalization study was performed for the small breaks. The results of the study are presented below.

   The purpose of the small break cases is to show that the containment pressure resulting from small breaks is bounded by the containment pressure resulting from the large break cases. The small break cases also demonstrate that the containment does not stay at the peak pressure in the long term and that the pressure decreases. The target for the containment depressurization rate is to reduce the containment pressure to half of the peak accident pressure of the most limiting case within 24 hours. For the BWRX-300, the decrease in the containment pressure in the long term is primarily accomplished by the isolation condensers as demonstrated below.

   A small break case was performed to maximize the containment pressure as presented in the GEH response to NRC Question 06.02.01-03 (eRAI 9862) (Reference R9862-1) using the base case [[ ]] nodes (the first number is the number of nodes in the x-direction, the second number is the number of nodes in the y-direction, and the last number is the number of nodes in the axial direction). This case uses the conservative inputs and model biases. In the nodalization study presented here, the same case was run using [[ ]] nodes. The results presented in the original GEH response to this NRC question (Reference R9862-2) contained a large conservatism in the containment response to small break cases, which was not intended. In this revised response, the condensation film thickness calculation was corrected to calculate the heat removal rate of the Passive Containment Cooling System (PCCS) units consistent with the method described in Section 6 of the LTR.

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The comparisons for the small break nodalization study are shown in Figure 9862-19.

The nodalization study cases were run until the Reactor Pressure Vessel (RPV) pressure falls below the containment pressure. Once the RPV and containment pressures equalize, the

containment pressure will not exceed the RPV pressure. There are two RPV pressures plotted in Figure 9862-19. The solid line is the RPV pressure with a small steam pipe break. This line is applicable until the break flow becomes unchoked. As discussed in the LTR, the break flow is calculated assuming no containment back pressure (i.e., the break flow is calculated assuming the containment remains at atmospheric pressure). When containment back pressure is not considered, the RPV pressure remains sufficiently above atmospheric pressure, and the break flow remains choked for 72 hours. The solid line is consistent with the cases presented in Chapter 5 of the LTR.

As the event progresses, the RPV pressure decreases and the containment pressure increases. Realistically, when containment back pressure is considered, the break flow becomes unchoked when the pressure differential between the RPV and the containment becomes low enough. The RPV and containment pressures eventually equalize, after which there is essentially no more mass discharged to the containment unless the containment pressure decreases at a faster rate than the RPV pressure. Instead of resolving exactly when the break flow becomes unchoked and when it stops, the upper and lower bounds for the RPV pressure are plotted in Figure 9862-19. The small break case is the lower bound (solid red line) and the no break case is the upper bound (dashed red line) for the RPV pressure. The actual RPV pressure would be between these two lines. The fact that the upper and lower bounds for the RPV pressure are close to each other indicates that the primary mechanism for the RPV depressurization is the heat removal by the isolation condensers, not the energy discharged by the break flow. As expected, with time, the RPV pressures calculated with and without break flow converge and continue to decrease together because the decreasing break flow with time becomes less important in determining the RPV pressure.

The containment pressure is calculated assuming no reduction in the break flow rate due to the containment back pressure. There are several containment pressures shown in Figure 9862-19 corresponding to the different nodalization cases. As an example, the containment pressure calculated for [[ ]] nodes is shown by the solid black line in Figure 9862-19. The containment and RPV pressures equalize at approximately [[ ]] in this case. Because the break flow to the containment is practically zero after this point for the remainder of the transient, the PCCS and containment dome are removing more energy from the containment than the energy being added from the RPV. As a result, the RPV and the containment pressure start to decrease. This is shown with the dashed black line in Figure 9862-19. When the containment pressure starts falling below the RPV pressure, there will be a small break flow again which prevents the containment pressure from falling much below the RPV pressure. However, the containment pressure will not exceed the RPV pressure in any case. It follows that the actual containment pressure is between the red dashed line and the black dashed line in Figure 9862-19. The plotted lines in Figure 9862-19 show that the long term containment pressures for all SBLOCA cases are reduced to less than 50% of the peak pressure from the LBLOCA in less than 24 hours (86,400 seconds).

The nodalization study was performed up to the point where the containment and RPV pressures equalize. The cases include [[ ]], in addition to the

base case of [[ ]] nodes. [[ ]]

The nodalization of the PCCS units in the axial direction is the same as the containment axial nodalization in all cases. In the base case, which has [[ ]] total axial nodes in the containment, the PCCS model has [[ ]] heated nodes in the axial direction and one (1) unheated node at the top representing the section of the PCCS above the containment, as shown in Figure 6-3 of LTR. The heated PCCS nodes are aligned with containment nodes [[ ]]. In the [[ ]] case, the PCCS has [[ ]] heated axial nodes aligned with containment axial nodes [[ ]] and one (1) unheated top node. In the [[ ]] case, the PCCS has [[ ]] heated nodes aligned with containment axial nodes [[ ]], and one (1) unheated top node.

The PCCS units are placed in one cell in the horizontal direction that is closest to their actual location.

The coarse nodalization case ([[ ]]), shown by the blue curve in Figure 9862-19, results in [[ ]]. As compared to the finer nodalization cases, this case [[ ]] the containment pressure. It can be concluded by comparing the results of the [[ ]] and [[ ]] cases that refinement of nodalization in the radial direction does not change the results. There is a small effect due to the nodalization in the axial direction. All cases display a similar pressure trend and magnitude. The peak pressure for the bounding accident, a large steam pipe break, is shown with a dotted-dashed line at approximately [[ ]] in Figure 9862-19. As shown, the containment pressure resulting from a small break is well below that of the large break case. In addition, the containment pressure in the long term is limited by the RPV pressure, and any calculated differences resulting from the nodalization scheme used in the containment small break analyses do not have an effect on the bounding long term containment pressure.

The steam volume fraction distributions in the containment are plotted in Figure 9862-20. The color palette is set to exaggerate any stratification effects. This figure shows that the [[ ]] nodalization underestimates the stratification, and consequently predicts lower steam fractions at the PCCS locations as compared to the steam fractions calculated using the finer nodalizations. As a result, the condensation rate is smaller and the containment pressure is higher than the other cases. The other nodalization schemes ([[ ]]) provide reasonably close results. The steam volume fraction distributions shown in Figure 9862-20 are consistent with the trends in pressure displayed in Figure 9862-19. The PCCS heat removal rate and temperatures are shown in Figures 9862-21 and 9862-22. As shown by the trends in Figure 9862-21, all the nodalizations indicate that the PCCS heat removal rates are, in the long term, approaching a similar asymptotic value that is sufficient to cause the containment to continue to depressurize as shown in Figure 9862-19. The reactor cavity pool is not being actively cooled so it will continue to heat up; however, the temperature difference between the pool and the PCCS exit temperature which is indicative of the heat removal rate remains approximately the same. Because decay heat is being removed by the

isolation condenser system, there is very little energy being deposited into the containment from the RPV after about [[ ]]. Even as the reactor cavity pool slowly heats up, the PCCS will continue to cool and depressurize the containment to an even lower value long term after the break flow becomes practically zero by moving energy that is already in the containment to the reactor cavity pool until the containment and reactor cavity pool temperatures approach within a few degrees of each other. Although there are some variations with nodalization, they do not have a significant effect on the containment pressure with nodalizations of [[ ]] and finer as shown in Figure 9862-19. The [[ ]] nodalization case overpredicts the containment pressure due to lack of resolution in steam stratification.

Based on the conclusions of the large break nodalization study and the results of the small break nodalization study discussed above, the use of the base case [[ ]] nodalization for the small break containment analyses is adequate and further refinement of the containment node size does not increase confidence in the results with respect to the purpose of the small break analyses.

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Figure 9862-19. Nodalization Study for Small Steam Pipe Breaks

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Figure 9862-20. Steam Volume Fraction Distribution in the Containment

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Figure 9862-21. Heat Removal Rates by the PCCS and the Steam Dome

Note: Negative values indicate heat removal from the containment.

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Figure 9862-22. PCCS Exit and Reactor Cavity Pool Temperatures

References

R9862-1 GEH Letter M210099, "Response to Requests for Additional Information (eRAIs) 9854, 9856, and 9862 and Supplemental Response to eRAI 9817 for Licensing Topical Report NEDC 33922P, Revision 0, BWRX 300 Containment Evaluation Method," September 17, 2021.

R9862-2 GEH Letter M210132, "Response to Request for Additional Information (eRAI) 9862 for Licensing Topical Report NEDC-33922P, Revision 0, BWRX-300 Containment Evaluation Method," October 29, 2021.

Proposed Changes to NEDC-33922P Revision 1

The following figures have been updated in Revision 2 of the LTR:

- Figure 6-2
- Figures 6-4 through 6-13
- Figures 6-15 through 6-17
- Figures 6-26 through 6-44

Table 6-6 and any text in the LTR affected by the modified figures have been updated in Revision 2 of the LTR.