TUELECTRIC

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Executive Vice President

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

SUBJECT: COMANCHE PEAK STEAM ELECTRIC STATION (CPSES)-UNIT 1
DOCKET NO. 50-445
REQUEST FOR ADDITIONAL INFORMATION ON RXE-89-002
VIPRE-01 CORE THERMAL-HYDRAULIC ANALYSIS METHODS

REF: Letter from the NRC to Mr. William J. Cahill, Jr. dated July 1, 1991, Requesting Additional Information regarding Topical Report RXE-89-002

Gentlemen:

Attached, please find TU Electric's response to the list of questions provided in the referenced letter.

Should clarification or additional information regarding responses to the referenced letter be required to enable the Staff to complete its review, contact Mr. Jimmy D. Seawright at 214/812-4375.

Sincerely,

William J. Cahill, Jr.

JDS/grp
Attachment

c - Mr. R. D. Martin, Region IV
Resident Inspectors, CPSES (2)
Mr. J. W. Clifford, NRR

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RESPONSES TO NRC QUESTIONS
ON
RXE-89-002

1. State the "intended licensing applications" of TUEC's VIPRE-01 methodology. Which input parameters does TUEC expect to have to change in "actual TU Electric licensing calculations"? Explain how these changes impact the validation analyses.

RESPONSE: TU Electric intends to use the VIPRE-01 methodology described in RXE-89-002:

a) to perform licensing safety analyses for the plant transients discussed in Chapter 15 of the CPSES FSAR using the methodology described in References 1, 2, and 3, and

b) to develop core safety limit lines (specifically the DNBR limit lines) to be used for reactor protection system setpoint analysis and Technical Specification safety limits.

When performing actual licensing calculations, input parameters which describe different fuel types and/or which describe different operating boundary conditions may be changed from the values used in the CPSES VIPRE-01 model described in RXE-89-002. Changes which may be required for different fuel types include geometry inputs, grid loss coefficients, and turbulent mixing coefficients. Different operating boundary conditions may include power peaking factors as well as system parameters such as pressure, temperature, flow and power.

The demonstration analyses in RXE-89-002 were performed with data representative of CPSES Unit 1 Cycle 1. Changes to the VIPRE input as described above will be made to the extent necessary to adequately represent future cycles. However, these types of changes do not alter the basic modeling methodology for which approval is requested.

2. Explain and justify the intended use for each of: (i) the steady-state model designated as the "reference case"; and (ii) the CPSES VIPRE-01 model. Explain which model will be used for licensing calculations.

RESPONSE: The steady-state model designated as the "reference case" in Chapter 5 of the report was only used to perform the sensitivity studies described in the report. The model referred to as the CPSES VIPRE-01 model represents the base model to be used for licensing calculations (with possible input parameter changes as described in the response to Question 1). The differences between the two models are discussed in the report and do not affect the conclusions of the sensitivity studies. Therefore, the conclusions of the sensitivity studies are valid for application to the CPSES VIPRE-01 model when performing licensing calculations.

3. What is the DNB limiting transient for CPSES? If it is other than the loss of flow transient, discuss and identify the impact that the limiting transient may have on the outcome of the sensitivity studies and selection of model options and input parameters.

RESPONSE: A single DNB limiting event is not defined for CPSES. A number of transients are analyzed (e.g., rod withdrawal at power, loss of flow, locked rotor, dropped rod) from a DNB perspective and, depending on the results, may be considered "DNB limited". That is, considering all the acceptance criteria for a particular transient, the DNB acceptance criterion may be the most challenged by the event and, therefore, DNB is considered to be the limiting acceptance criterion for the event.

The objective of the sensitivity studies is to establish either the insensitivity of the VIPRE results to changes in the modeling options/inputs or the trend of the VIPRE results caused by changes to the modeling options/inputs. The results of the sensitivity studies can then be used to assess the conservatism of future analyses with respect to the modeling options and input parameters selected. The conclusions of the sensitivity studies, i.e., the insensitivity of the VIPRE results or the trend of the VIPRE results to changes in VIPRE inputs, are not dependent on the transient being analyzed. This was shown by evaluating the changes to DNBR at two different operating conditions, nominal operating conditions and loss of flow operating conditions.

4. Provide a detailed description of and justify the data used for the following:

   a. active fuel length
   b. the choice of a factor for core flow maldistribution
   c. grid loss coefficient
   d. uniform grid spacing
   e. damping factor
   f. gap/centroid distance
   g. slip ratio
   h. turbulent mixing coefficient, ABETA
   i. core bypass flow assumed
   j. pitch reduction factor (Section 5.1).

RESPONSE: The CPSES VIPRE-01 model described in the report represents Westinghouse standard 17X17 fuel with R-type mixing vane grids. Future reloads with different fuel types may require changes to the model description; however, these will be justified on a cycle-specific basis as required.

a. The active fuel length is defined to be the length of the fuel over which power is produced. This data is obtained from the fuel vendor.

b. The core inlet flow maldistribution is selected to reduce the inlet flow to the hot assembly by 5% of the nominal mass flux. This is consistent with the current licensing analysis methodology as described in the CPSES FSAR. Sensitivity studies of core inlet flow maldistribution performed by TU Electric show that the inlet flow maldistribution has little effect on the MDNBR. The core inlet flow maldistribution is recovered in the first few feet of the core, well below the height at which the MDNBR occurs. The 5% flow reduction to the hot assembly will continue to be used for consistency with the existing licensing analyses.

c. The grid loss coefficients are obtained from the fuel vendor from fuel assembly hydraulic test data. The loss coefficients are obtained as bundle average loss coefficients and are converted to channel dependent loss coefficients as described in the report. This method is consistent with the development of the TUE-1 CHF correlation (Reference 6). Sensitivity studies performed by TU Electric show that the predicted MDNBR varies very little with changing values of the bundle average grid loss coefficient, i.e., if the grid loss coefficients for all channels are changed uniformly.

d. The grid spacing is obtained from the fuel vendor. The grid loss coefficients are allocated to the axial span which contains the grids according to this spacing.

e. The damping factor used in a given analysis will be adjusted in order to optimize the code efficiency and to ensure solution convergence. A sensitivity study was performed by TU Electric using various damping factors. The results showed that as long as the solution converged, the calculated MDNBR changed very little for different damping factors.

f. The gap width and centroid distance for subchannels are input as the nominal rod-to-rod gap width and rod pitch dimensions, respectively. For lumped channels, the gap is taken to be the sum of the gap widths through which the respective channels communicate. No reduction in the gap width is modeled for either pitch reduction or rod bow. The centroid distance is taken to be the maximum lateral distance between channel centroids through any of the gaps through which the channels communicate. A sensitivity study on centroid distances performed by TU Electric showed virtually no MDNBR change for different centroid distances. This method is consistent with the VIPRE modeling guidelines in Reference 6.

g. The CPSES VIPRE-01 modeling methodology uses the EPRI correlations for two-phase flow friction multiplier, subcooled boiling, and bulk boiling. The EPRI correlations were developed to account for the effects of phase slip on the void fraction without the need to specify a slip ratio. Therefore, a slip ratio is not required input for the CPSES VIPRE-01 modeling methodology.

h. The value of the turbulent mixing coefficient, ABETA, used for the Westinghouse 17X17 fuel with R-type mixing vane grids is based on interchannel mixing tests conducted by Westinghouse. The value used in the CPSES VIPRE-01 model is 0.038 which is conservatively low considering the best estimate value for 26" grid spacing is 0.059 and increases for decreased grid spacing. (The grid spacing in the CPSES VIPRE-01 model is 20.55".) Values of ABETA used for other grid types or fuel types will be based on vendor test data. In the absence of any test data, conservative values of ABETA will be used and justified on the basis of grid type and comparison to other similar grid types for which test data does exist.

i. The core bypass flow of 5.8% assumed in the CPSES VIPRE-01 model described in RXE-89-002 is based on the current licensing analysis as discussed in the CPSES FSAR. The bypass flow occurs because of the existence of parallel flow paths around the core. The flow distribution through these parallel paths and the core is a function of the flow resistances for each of the parallel paths and the core. A relatively constant core flow resistance will yield a constant flow distribution through the core and the parallel flow paths. There is sufficient margin in the 5.8% value to accomodate minor increases in the core resistance or decreases in the parallel paths equivalent resistance, either of which would push more flow to the bypass flow paths.

j. The pitch reduction factor discussed in Section 5.1 of the report was modeled by reducing the gap widths for the hot channels by 0.0073 inches (Reference 4). The pitch reduction factor is only included in the "reference case" which was used in performing the sensitivity study. Pitch reduction is not modeled in the CPSES VIPRE-01 model.

5. Justify, by providing sensitivity study results, that the selection of the following parameters result in conservative and stable MDNBR prediction:

   a. convergence criteria
   b. time step sizes.

   RESPONSE: The direct UPFLOW solution technique is used in the CPSES VIPRE-01 modeling methodology. Sensitivity studies discussed in Reference 7 have shown that this solution technique is insensitive to changes in convergence criteria. For example, the Reference 7 study shows that the difference in crossflow velocity for a case with loose convergence criteria that converged in only 4 iterations and a case with tight convergence criteria that took 100 iterations to converge was only about 1%. In addition, a sensitivity study was performed by TU Electric to evaluate the effects of changing the axial flow convergence criteria. In this study, when the convergence criteria was doubled, the calculated MDNBR changed by less than 1%. These results show that, for converged solutions, the calculated MDNBR is not sensitive to the convergence limit specified.

VIPRE has no upper limit on time step size for stability, but two options available in VIPRE (the pressure drop boundary condition option and the subcooled boiling and bulk void model option) can yield instabilities in transient calculations if time step sizes are too small. The problems associated with these options are discussed in Reference 7 and will be considered when either of the two options is selected for a transient analysis. In spite of this, the selection of an appropriate time step size is still dependent on the transient being analyzed because the time step should be kept small enough to resolve the details of the transient. Sensitivity studies discussed in Reference 7 were performed for a transient with a combined power and flow decay. The flow and power decrease linearly by 50% in 0.5 seconds starting at 0.0 seconds and 1.5 seconds, respectively, into the transient. Time steps of 1.0, 0.5, 0.1, and 0.05 seconds were used. The results for the time steps of 0.05 and 0.1 seconds were very similar. The 0.5 second time step run began to lose some of the details of the transient even though the trends were consistent with the smaller time step runs. The results for the 1.0 second time step run yielded nonconservative predictions of the MDNBR. Therefore, time step size selection will be based on the rate of change of important parameters during the transient.

6. Discuss how a bounding value for the gap conductance is determined on a transient specific basis.

RESPONSE: The gap conductance is required as input when the fuel rod conduction model is utilized in a transient analysis. Bounding values, i.e., an upper limit and a lower limit, of the gap conductance will be determined by a detailed fuel performance analysis. The gap conductance used for a particular transient will be one which yields conservative calculational results with respect to the event acceptance criteria.

7. TUEC uses a dummy rod model to represent the fuel rods for steady-state DNB analysis. Explain how the rod surface heat flux is computed for input to the VIPRE-01 model.

RESPONSE: The system transient analysis code, RETRAN-02, is used to calculate the power response of the core to various perturbations in the system. The output from RETRAN provides the fractional core power, both nuclear and thermal, as a function of time. The fractional thermal power at the transient time of interest is then multiplied by the nominal linear power (kW/ft/rod) which represents 100% of nominal core power. (The nominal linear power is calculated based on the total nominal core power, the active fuel length, and the number of fuel rods in the core.) This value of linear power per rod, instead of the rod surface heat flux, is then input into VIPRE. VIPRE interprets the linear power per rod to include the fraction of power produced in the moderator. Therefore, VIPRE computes the rod surface heat flux by reducing the linear power per rod by the user input fractional power produced in the moderator.

8. Justify use of a 1/8 core symmetric base model to analyze asymmetric transients including the MSLB transient. Provide a detailed discussion of how the MSLB DNBR calculations are performed.

RESPONSE: The physical location of the hot assembly in the core is virtually transparent to VIPRE even in the 1/8 core model. Therefore, the 1/8 core model could be used to analyze asymmetric transients as long as appropriate changes to the lumped channel parameters are made to define appropriate channel connections. However, in spite of the fact that the 1/8 core model could be used, a full core model has been developed for analyzing the MSLB event at hot zero power to facilitate resolving the asymmetric flow, core inlet temperature, and power distributions in the core. This full core model is described in Reference 3. At present, the MSLB at hot zero power is the only transient which utilizes the full core model.

9. Provide and justify that the data used for the following are conservative or provide references of prior approval of their use: (i) hot channel factor, (ii) axial power profile and its peaking factor, (iii) radial peaking factor and pin radial-local peak; and (iv) engineering enthalpy rise hot channel factor.

RESPONSE: The analyses submitted in the report, RXE-89-00[illegible], are provided for demonstration purposes only. The values of the above factors selected for the demonstration analyses are those used in the current licensing analyses. The values to be used in future licensing analyses will be determined as follows:

(i) Hot channel factor: The hot channel factors used in the DNB analyses are discussed in items (ii), (iii), and (iv) below.

(ii) Axial power profile and its peaking factor: Numerous axial power profiles are generated by reactor physics calculations for normal operations as described in Reference 5. Each of these power profiles is then evaluated from a DNB perspective to identify the limiting axial power profile. The limiting axial power profile is then utilized in the DNB analysis. The conservatism of this axial power profile will be confirmed for each event analyzed.

(iii) Radial peaking factor and pin radial-local peak: The radial peaking factor, also referred to as the nuclear enthalpy rise hot channel factor, is set equal to the limiting Technical Specification value. The pin radial-local peak is conservatively selected as a relatively flat pin power distribution around the hot channels. This is based on sensitivity studies performed by TU Electric which examined several pin power distributions.

(iv) Engineering enthalpy rise hot channel factor: This factor is obtained from the fuel vendor.

10. Discuss further and justify not using an engineering heat flux hot channel factor (Section 6.6). Since not using this factor results in a 3% increase in the MDNBR, explain the statement "no additional DNBR penalty is required" to account for this effect. Similarly, discuss and justify not using a hot channel pitch reduction factor which is worth 3% in the predicted MDNBR.

RESPONSE: The discussion in Section 6.6 subparagraph 2) is intended to identify the reasons that the CPSES VIPRE-01 model predicts higher values of MDNBR than that reported in the FSAR. The current FSAR analysis includes a penalty factor on the THINC calculated MDNBR to account for the engineering heat flux hot channel factor. Westinghouse has since demonstrated that there is no DNB penalty for the relatively low intensity heat flux spikes caused by variations in fabrication parameters. TU Electric also performed an evaluation using VIPRE-01 and the TUE-1 correlation. The results of this evaluation likewise show that no additional DNBR penalty is required to account for heat flux spikes. Therefore, the CPSES VIPRE-01 modeling methodology does not include a penalty for the engineering heat flux hot channel factor.

Similar to the above, the current FSAR analysis includes the effects of hot channel pitch reduction in the core thermal-hydraulic analysis. The CPSES VIPRE-01 modeling methodology does not include hot channel pitch reduction. As discussed above, the discussion in Section 6.6 subparagraph 4) is only intended to identify another reason for the differences in the CPSES VIPRE-01 results and the FSAR results. The effects of pitch reduction will be compensated for by the rod bow penalty to be calculated for CPSES. This manner of treating pitch reduction is consistent with the Westinghouse method.

11. In the benchmark analyses TUEC used a constant value for some system parameters, such as inlet temperature and system pressure for the loss of flow transient, obtained from the current FSAR. Since in future licensing calculations, TUEC intends to use RETRAN-02 to generate the boundary conditions, discuss, in-depth by providing comparison of a limiting transient case, the impact expected on the DNB calculations, the MDNBR and model option selections.

    RESPONSE: The use of RETRAN-02 to generate boundary conditions will not affect the manner in which the boundary conditions are used in VIPRE. As long as a conservative set of boundary conditions is input into VIPRE and the conservative modeling methodology described in RXE-89-002 is applied, the VIPRE results will be conservative. In some cases, to ensure conservatism, it may be necessary to hold certain parameters constant at their initial values. In other cases, it may just be convenient, as well as conservative, to use the initial values for the entire transient. Still, in other cases, the time histories of all of the boundary conditions as calculated by the system code may be input as forcing functions into VIPRE. Whichever method is used, the boundary conditions will be selected to ensure the VIPRE results are conservative. Regardless of the method, the VIPRE modeling methodology, for which approval is requested, will not be affected by the source of the boundary conditions input into the VIPRE model.

    The loss of flow demonstration analysis in the report is an example of a transient analysis in which the pressure and core inlet temperature are held constant at their initial values. (This is consistent with the current FSAR analysis.) The use of the low initial pressure throughout the transient is conservative because pressure would actually increase which would increase the calculated MDNBR. The high initial core inlet temperature is used because the reactor trip and MDNBR occur within 5 seconds of the event initiation. Such a short period of time would not allow any significant heatup of the reactor coolant entering the core. Therefore, the use of the initial core inlet temperature throughout the transient is acceptable for the DNB analysis.

12. Describe in detail how the DNBR penalty due to the rod bow effect will be determined and accounted.

RESPONSE: Currently, the DNBR penalty due to the rod bow effect has not been calculated using the CPSES VIPRE-01 model. Once the rod bow DNBR penalty has been determined, it will be accounted for by allocating a portion of the generic margin for rod bow effects. (The "generic margin" represents the difference between the 95/95 DNBR limit for the TUE-1 correlation (Reference 6) and the DNBR design limit. The DNBR design limit is set higher than the 95/95 DNBR limit in order to retain sufficient margin to offset DNBR penalties for generic issues such as rod bowing.) The rod bow analysis will follow a similar approach as discussed in References 8 and 9.

13. Do you intend to use VIPRE to calculate the hot leg boiling limit and steam generator safety valve lines for the core safety limits (Section A1.3)? If so, provide comparison between your VIPRE calculations and th FSAR calculations.

RESPONSF: No, the hot leg boiling limit lines and the steam generator safety valve opening lines are calculated as described in Reference 5.

REFERENCES

1. Sui-Sang Lo, et. al., RXE-91-001, "Transient Analysis Methods for Comanche Peak Steam Electric Station Licensing Applications", February 1991.

2. Dean W. Throckmorton, et. al., RXE-91-002, "Reactivity Anomaly Events Methodology", May 1991.

3. Mark A. Grace and Richard M. Rubin, RXE-91-005, "Methodology for Reactor Core Response to Steamline Break Events", May 1991.

4. H. Chelemer, et. al., WCAP-8567, "Improved Thermal Design Procedure", July 1975.

5. John T. Bosma and Mark A. Grace, RXE-90-006-P, "Power Distribution Control Analysis and Overtemperature N-16 and Overpower N-16 Trip Setpoint Methodology", February 1991.

6. Huan B. Giap and Yi-Xing Sung, RXE-88-102-P, "TUE-1 Departure from Nucleate Boiling Correlation", January 1989.

7. EPRI NP-2511-CCM, "VIPRE-01: A Thermal-Hydraulic Code for Reactor Cores", Volumes 1 through 5.

8. J. R. Reavis, et. al., WCAP-8691, "Fuel Rod Bowing", December 1975

9. T. L. Krysinski, et. al., XN-75-32(P)(A) Supplement 1, 2, 3, & 4, "Computational Procedure for Evaluating Fuel Rod Bowing", October 1983.