ATTACHMENT A

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TECHNICAL EVALUATION REPORT
FIBWR AND TCPPECO COMPUTER PROGRAMS

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ABSTRACT

The Idaho National Engineering Laboratory reviewed the FIBWR and TCPPECO computer programs developed by Philadelphia Electric Company (PECO). PECO uses FIBWR to perform steady state, thermal-hydraulic analyses of boiling water reactors (BWRs). TCPPECO is used with RETRAN to calculate the critical power ratio (CPR) in BWRs. PECO submitted these programs for Nuclear Regulatory Commission approval for use in their in-house reload licensing analyses. The review consisted of evaluating the modifications PECO made to methods previously approved for use by Yankee Atomic Electric Company (YAEC). Assessment calculations made by PECO for each code were also reviewed. This review found the modifications PECO made to the approved YAEC methods should not significantly affect the calculated results and, therefore, recommends the PECO methods be approved for use in licensing analyses on the basis that suggested conditions and requirements are followed.

SUMMARY

This report documents the review and evaluation of the Philadelphia Electric Company (PECO) computer programs FIBWR and TCPPECO. FIBWR calculates the steady state pressure drop and flow and void distribution in a boiling water reactor (BWR) core. TCPPECO is used with RETRAN to calculate the critical power ratio (CPR) in BWRs. PECO submitted these programs for Nuclear Regulatory Commission (NRC), Office of Nuclear Reactor Regulation (NRR), approval for use in their in-house reload licensing analyses. NRR requested assistance from the Idaho National Engineering Laboratory (INEL) in reviewing FIBWR and TCPPECO. FIBWR and the RETRAN-TCPPECO methodology are based on methods previously approved for use in licensing analyses of the Vermont Yankee Nuclear Power Station by Yankee Atomic Electric Company (YAEC).

The review consisted of evaluating the PECO modifications to the methods previously approved for use by YAEC. PECO assessment calculations for each code were also reviewed. INEL completed this review using the information supplied by PECO in reports documenting FIBWR, the RETRAN-TCPPECO methodology, and the FIBWR and RETRAN-TCPPECO assessment calculations and in letters to the NRC listing the changes PECO made to the approved YAEC methods and responding to an NRC question on the RETRAN-TCPPECO assessment calculations.

This review found the modifications PECO made to the approved YAEC methods should not significantly affect the calculated results and, therefore, recommends the PECO methods be approved for use in licensing analyses on the basis that suggested conditions and requirements are followed.

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TECHNICAL EVALUATION REPORT

FIBWR AND TCPPECO COMPUTER PROGRAMS

1. INTRODUCTION

FIBWR[1] and TCPPECO[2] are computer programs submitted by Philadelphia Electric Company (PECO) to the Nuclear Regulatory Commission (NRC) for approval for use in their in-house reload licensing analyses. FIBWR calculates the steady state pressure drop and flow and void distributions in a boiling water reactor (BWR) core. TCPPECO is combined with the RETRAN[3] code to calculate critical power ratios (CPRs) in BWRs and will be used to calculate the transient CPR for Peach Bottom Units 2 and 3. Both FIBWR and the RETRAN-TCPPECO methodology are based on methods previously approved by the NRC for licensing use by Yankee Atomic Electric Company (YAEC).[4]

The Office of Nuclear Reactor Regulation (NRR) has the responsibility to evaluate and review computer codes and their proposed applications. NRR requested the Idaho National Engineering Laboratory (INEL) to provide assistance in the review of FIBWR and RETRAN-TCPPECO. Specifically, the INEL reviewed the changes made by PECO to the previously accepted methods and evaluated the acceptability of the changes.

This technical evaluation report contains the results of the FIBWR and RETRAN-TCPPECO review and assessment. Section 2 briefly describes the FIBWR code and the changes made by PECO. The results of PECO's FIBWR assessment calculations are also discussed. Section 3 presents the same information for RETRAN-TCPPECO. PECO's proposed method of calculating transient CPRs is discussed in Section 4. The conclusions are summarized in Section 5 and the references are listed in Section 6.

2. FIBWR CODE REVIEW

This section briefly describes the FIBWR code and identifies the changes made by PECO. The results of assessment calculations made by PECO are also discussed.

2.1 Description of FIBWR Code and Modifications

PECO uses FIBWR to perform steady state, thermal-hydraulic analyses of BWRs. FIBWR evaluates the flow and void distribution within the reactor core by solving the steady state, one-dimensional equations of continuity, momentum, and energy. FIBWR was developed by YAEC and made available to PECO through the Electric Power Research Institute (EPRI). The NRC reviewed and approved FIBWR for use in performing licensing calculations for the Vermont Yankee Nuclear Power Station (Reference 4).

PECO made only minor changes to FIBWR. According to the changes identified by PECO,[5] only the capability to print out additional variables was added to the code. The basic models the NRC approved earlier were not changed. Therefore, the code is essentially the same as that previously approved for use by YAEC.

2.2 FIBWR Assessment Calculations

To assess the capability of FIBWR to calculate the core support plate pressure drop and the core bypass flow, PECO compared FIBWR results to data available from the Peach Bottom 2 and 3 plant process computers. PECO provided these results for review.[6] Using the ratio of the FIBWR calculated value to the process computer value (1.0 would indicate perfect agreement), PECO showed the mean of this ratio varied between 0.925 and 1.013 for the pressure drop and 1.011 to 1.044 for the bypass flow. This comparison showed that FIBWR adequately calculated the plant data.

2.3 Conclusion

Because no significant changes were made to a previously approved code and the PECO assessment calculations showed FIBWR could adequately calculate the Peach Bottom 2 and 3 core support plate pressure drop and core bypass flow, it is recommended that FIBWR be accepted for licensing analyses. Because the acceptability of the PECO version of FIBWR is based on the earlier acceptance of the YAEC version of FIBWR, any restrictions on the YAEC version of FIBWR noted in the safety evaluation report (SER) also apply to the PECO version of FIBWR.

3. RETRAN-TCPPECO METHODOLOGY

This section briefly describes the RETRAN-TCPPECO methodology and identifies the changes made by PECO in developing TCPPECO. The results of assessment calculations made by PECO are also discussed.

3.1 Description of RETRAN-TCPPECO Methodology and Code Modifications

PECO uses TCPPECO, in conjunction with the RETRAN code, to calculate the CPR in BWRs. The overall system response is calculated with RETRAN and these results provide the boundary conditions to a RETRAN hot channel model. The results of the RETRAN hot channel model are then input to TCPPECO to calculate the CPR. TCPPECO uses the GE proprietary GEXL correlation[7] to determine when the critical quality is reached at a specific core location. TCPPECO uses an iterative procedure to determine the CPR (see Figure 1). An initial CPR estimate is made and the boiling length and local quality are recalculated based on this estimate. The critical quality from the GEXL correlation is calculated based on the recalculated boiling length and compared to the revised local quality. If the revised local quality and the critical quality from the GEXL correlation agree (within a specified tolerance), the CPR is set equal to the initial estimate. If the local quality and the critical quality do not agree, a new CPR estimate is made and the code makes another iteration. This continues until the revised local quality and the critical quality converge.

PECO based TCPPECO on the YAEC code TCPYA01. The NRC reviewed and approved the RETRAN-TCPYA01 methodology for use in performing licensing calculations (Reference 4). PECO made a number of changes to TCPYA01 in their development of TCPPECO and they identified these changes in Reference 5. The changes include using a different interpolating routine in calculating the boiling length, changing the calculation of the thermal diameter to account for differences in the diameter of the fuel rods and the water rods, and also some input/output changes. These changes should not result in significantly different results when compared to those calculated with TCPYA01.

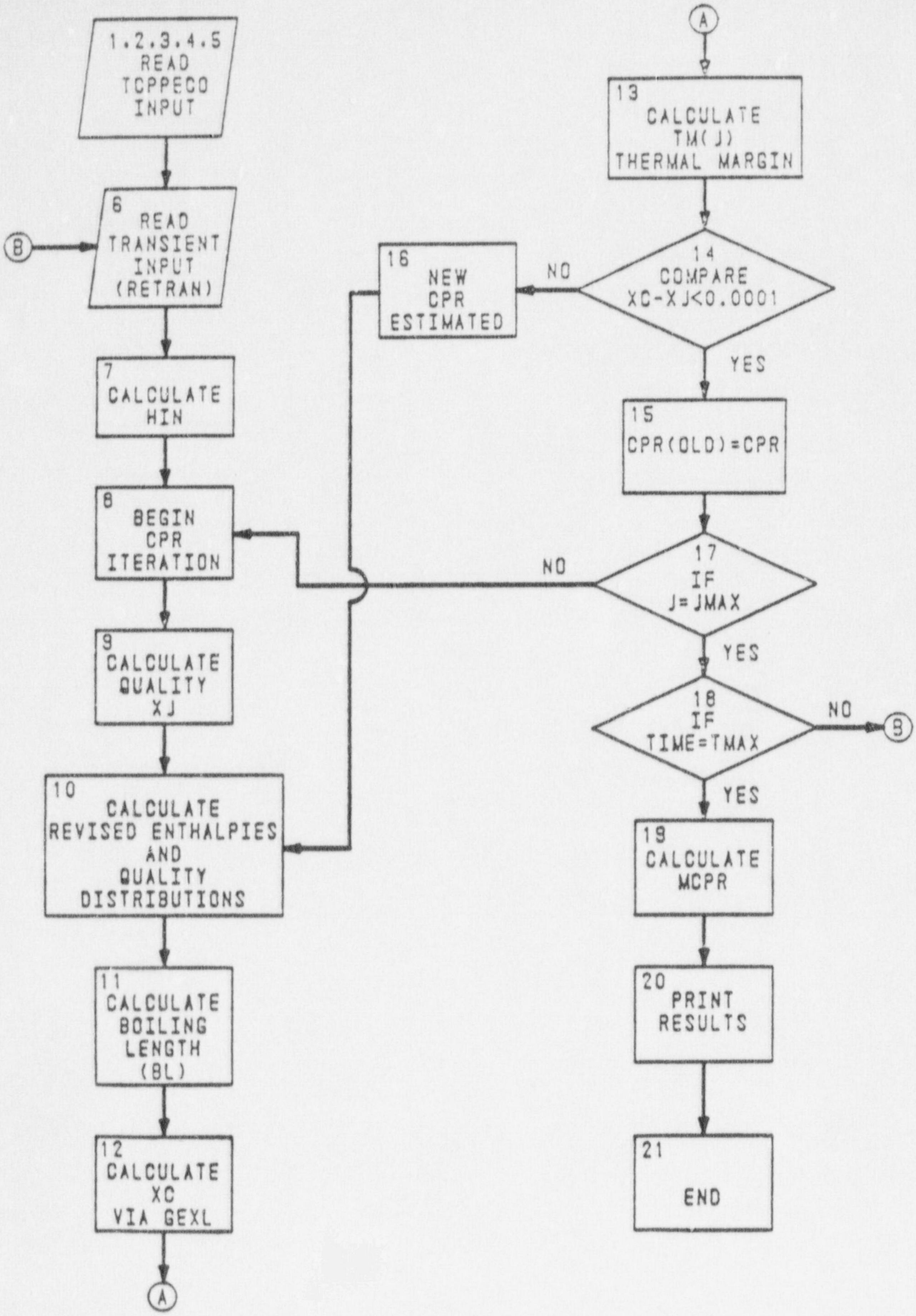

Figure 1. Flow Diagram for TCPPECO.

3.2 RETRAN-TCPPECO Assessment Calculations

To assess the capability of RETRAN-TCPPECO to calculate boiling transition, PECO compared RETRAN-TCPPECO results to data available from GE-ATLAS tests.[8,9] These results were presented in Reference 2. PECO analyzed fifty steady state tests with RETRAN-TCPPECO. The minimum CPRs (MCPRs) calculated fall into the range of 0.973 to 1.053. The mean was 1.007 with a standard deviation of 0.019. These results indicate there is some scatter in the calculated CPRs but all of the calculated steady state results are well within the GEXL MCPR limit of 1.07. The limit of 1.07 is used to account for uncertainty in the GEXL correlation by assuming boiling transition occurs if the MCPR is less than or equal to 1.07 instead of the mathematical MCPR limit of 1.0.

For the transient tests analyzed, RETRAN-TCPPECO calculated the measured time to boiling transition within one second except for three tests. One of these tests was a flow decay at constant power (Run 112) and the other tests were flow and power increase transients (Runs 229 and 231). PECO responded to a request for additional information on these analyses in Reference 10. For Run 112, a MCPR of 1.011 was calculated at 7.75 s as compared to a time to boiling transition of 6.29 s in the experiment. PECO noted the calculated CPR for Run 112 was within the mean plus one standard deviation of the steady state calculated CPRs, 1.026, and fell below 1.026 at approximately 6.25 s. Thus, the results for Run 112 fall within the scatter of the steady state data. PECO provided a similar reason for the difference between the calculated and measured results for Run 231. For Run 229, PECO noted that, although there was a boiling transition at 4.17 s, the data indicated that the thermocouple rewet very soon after that. This occurred several times between 4.17 s and 15 s. At approximately 15.5 s boiling transition occurred and the thermocouple did not rewet. For Run 229, the calculated MCPR was 1.008 at 18.2 s but the calculated CPR fell below 1.026 at about 15.6 s. PECO stated that, based on these results and the fact that boiling transition was not sustained until 15.5 s, the calculation for Run 229 adequately represented the test data and was within the scatter of the steady state results. Thus, PECO concluded the RETRAN-TCPPECO results for these tests represent the test data well and do not indicate code or methodology problems even though MCPRs of 1.0 or less were not calculated for these tests.

INEL reviewed the SER for the YAEC RETRAN-TCPYA01 methodology (Reference 4) to determine how the RETRAN-TCPYA01 results for the GE-ATLAS tests compared to those discussed above. This review found the RETRAN-TCPYA01 results for the steady state tests similar to those calculated with RETRAN-TCPPECO. In addition, RETRAN-TCPYA01 did not calculate a MCPR of 1.0 or less for some of the transient tests. Although several reasons were given why RETRAN-TCPYA01 did not calculate a MCPR of 1.0 in these tests, the authors of the SER considered the RETRAN-TCPYA01 results acceptable because the MCPR was within the GEXL correlation MCPR limit of 1.07 for those cases where boiling transition was not calculated. Thus, the RETRAN-TCPYA01 results were accepted for reasons very similar to those presented by PECO for RETRAN-TCPPECO.

Based on the information received from PECO and our review of the YAEC SER, the INEL concluded RETRAN-TCPPECO acceptably calculated the test results. PECO's statement that their transient analyses where boiling transition was not calculated are adequate because the results fall within the mean plus one standard deviation of the steady state data (1.026) is acceptable and is supported by the acceptance of the YAEC results because they were within the GEXL MCPR limit of 1.07. It should be noted that PECO also applies a MCPR upper bound of 1.07 for licensing calculations (Reference 10).

PECO assessed the sensitivity of the RETRAN-TCPPECO method to core nodalization (12 axial nodes versus 24 nodes), void models (Homogeneous Equilibrium Model (HEM) versus EPRI void model), and time step size (0.05 s maximum, 0.01 s minimum versus 0.005 s maximum, 0.001 s minimum or a fixed time step of 0.025 s). These studies showed the calculated results were not sensitive to these parameters over the ranges studied.

Therefore, active core nodalizations using 12 to 24 nodes would be acceptable, either the HEM or EPRI void model may be used, and time steps bounded by a maximum of 0.05 s and a minimum of 0.001 s would be acceptable for use in licensing calculations.

3.3 Conclusion

Because the changes made to a previously approved method should not significantly change the calculated results and the assessment calculations provided by PECO showed RETRAN-TCPPECO could adequately calculate the GE-ATLAS transient tests, it is recommended that the RETRAN-TCPPECO methodology be accepted for licensing analyses. Because the acceptability of RETRAN-TCPPECO is based on the earlier acceptance of the YAEC methodology using RETRAN-TCPYA01, any restrictions on RETRAN-TCPYA01 noted in the SER also apply to RETRAN-TCPPECO.

4. PEACH BOTTOM 2 AND 3 TRANSIENT CPR METHODOLOGY

PECO intends to use RETRAN-TCPPECO and FIBWR to calculate the transient CPR response for Peach Bottom 2 and 3. The methodology proposed is shown in Figure 2 which was taken from Reference 2. The methodology is based on that discussed in Section 3.1 except a check is added after the TCPPECO run is completed. This check determines whether the MCPR calculated by TCPPECO is equal to 1.07. If it is, then the transient CPR difference is calculated. If not, the estimated hot channel power and flow are adjusted and the RETRAN hot channel model is rerun to start the CPR calculation cycle again.

PECO presented the RETRAN hot channel nodalization for Peach Bottom 2 and 3 in Reference 2. The model uses 24 axial nodes to represent the active core which is adequate based on the sensitivity study discussed in Section 3.2. The other options and models to be used in PECO's RETRAN system and hot channel analyses were not discussed. These should be reviewed to ensure they are consistent with current modeling practices, based on the GE-ATLAS assessment calculations, or based on the sensitivity studies performed by PECO Any exceptions should be justified.

PECO presented the results of one plant analysis using this methodology to calculate the transient CPR difference. The case presented was a generator load rejection without bypass transient. A MCPR of 1.07 was calculated at 1.1 s. Because the initial CPR was 1.36, the CPR difference for the transient was 0.29. No plant data was compared to the calculation but the analysis results reviewed appear reasonable.

The methodology proposed by PECO is based on methods that are recommended for approval in this report (PECO version of FIBWR and RETRAN-TCPPECO) and are very similar to methods previously approved by the NRC. The methodology shown in Figure 2 combines these methods in a way consistent with their intended use. Thus, there are no problems due to code interaction. Therefore, it is recommended that this methodology be approved for use by PECO in calculating transient CPRs provided the the RETRAN model options are reviewed as discussed above.

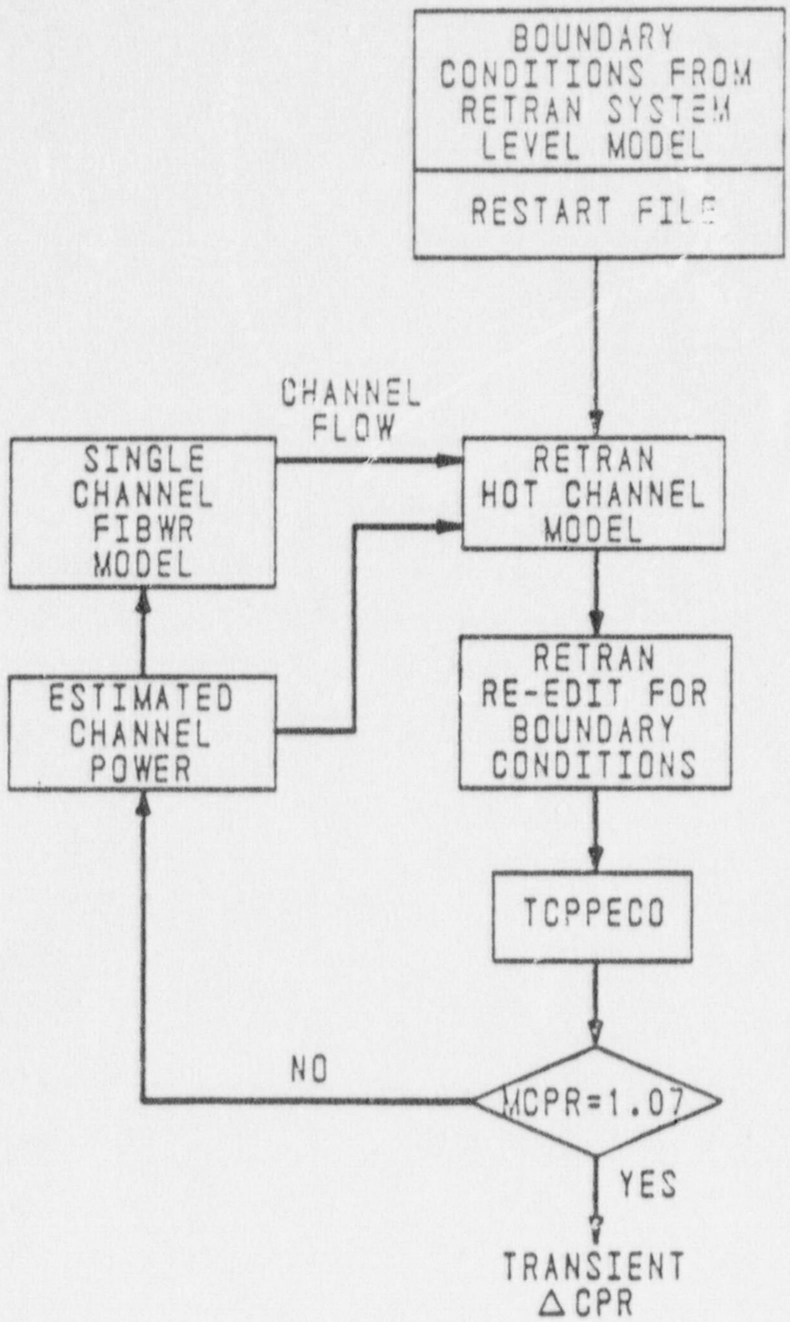

Figure 2. RETRAN-TCPPECO methodology for calculating transient CPRs.

5. CONCLUSIONS

The following summarizes the conclusions drawn from FIBWR and RETRAN-TCPPECO reviews:

1. The INEL reviewed the PECO version of FIBWR and the RETRAN-TCPPECO methodology and recommends they be accepted for licensing analyses with the following restriction. Because the acceptability (in part) of the PECO versions of FIBWR and RETRAN-TCPPECO is based on the earlier acceptance of the YAEC versions of FIBWR and RETRAN-TCPYA01, any restrictions on the YAEC methods noted in the SER also apply to the PECO methods.

2. The RETRAN hot channel nodalization (24 axial nodes) for the Peach Bottom 2 and 3 active cores is adequate based on the sensitivity study discussed in Section 3.2. Other options and models to be used in the RETRAN system and hot channel analyses for Peach Bottom 2 and 3 were not discussed. They should be reviewed to ensure they are consistent with current modeling practices, based on the GE-ATLAS assessment calculations, or based on the sensitivity studies performed by PECO. Any exceptions should be justified.

3. The INEL reviewed the methodology proposed by PECO for calculating transient CPRs and recommends the methodology be approved for licensing use provided FIBWR and RETRAN-TCPPECO are used in accordance with the limitations noted above.

6. REFERENCES

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