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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ON "QUALIFICATIONS OF REACTOR PHYSICS METHODS FOR

APPLICATION TO KEWAUNEE" REPORT

Report Title:	Qualification of Reactor Physics Methods for Application to Kewaunee (Proprietary)
Report Date:	September 29, 1978
Originating Organization:	Wisconsin Public Service Corporation
Reviewed by:	Core Performance Branch, DSS
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Summary of Report

This report describes the reactor physics methods used by Wisconsin Public Service (WPS) for their analysis of the first three cycles of the Kewaunee Nuclear Power Plant. The report addresses the reactor model description, the qualification and quantification of reliability factors, and the application of the physics methods to both reactor operations and to reload safety evaluations.

The computer model used to analyze Kewaunee is the Advanced Recycle Methodology Program (ARMP) developed by Nuclear Associates International Corporation (NAI) under the sponsorship of Electric Power Research Institute (EPRI). The ARMP computer system is composed of individual computer programs including the following physics related ones:

1. EPRI-CELL, a special code which is used to generate initial and burnup dependent nuclide concentrations and few group neutron cross sections.

2. PDQ7/HARMONY, a two-dimensional diffusion-depletion code which is used to calculate local peaking factors as well as for generating input data for the three-dimensional nodal code.

3. EPRI-NODE-P, a three-dimensional nodal code which is used to obtain core power distributions as well as core physics parameters such as control rod worths and reactivity coefficients.

4. CPM, a multi-group collision probability transport code which is used to provide lumped absorber data for burnable poisons and control rods.

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The ARMP model is verified by benchmarking against Kewaunee measurements over the first three cycles of operation. Reliability factors, describing the allowances to be used in safety-related calculations to assure conservatism, and uncertainty factors, describing the actual model accuracy, are evaluated by direct comparison of calculations to experimental data. The following physics parameters are addressed:

1. control rod worth comparison to measurement,
2. isothermal temperature coefficient comparison to measurement,
3. power distribution comparisons to measurement,
4. peak-to-average fuel pin power comparisons to measurement, and
5. burnup dependent isotopic composition comparisons to measurement.

For each parameter addressed the data base is presented, including comparisons between calculations and measurements as well as the uncertainty and reliability factors of the calculation, and conclusions are drawn regarding the suitability of the model to perform the calculations.

Summary of Review

We have reviewed the information presented with regard to calculational methods and comparisons of calculations and experiment. Although the ARMP computer system was used to analyze the Kewaunee cores, the report emphasizes the implementation of the WPS ARMP model since the detailed code descriptions are available in the EPRI ARMP documentation, "Advanced Recycle Methodology Program System Documentation." CCM-3 Research Project 118-1, September 1977. Therefore, we did not review the ARMP system, per se, but rather the qualification of its use in determining physics parameters for application to the Kewaunee core.

Many of the computer programs used in the ARMP system are acceptable industry-wide codes and, therefore, require no additional review. These include the GAM, THERMOS, and CINDER programs, which form the neutron cross-section generator; EPRI-CELL; and PDQ7, the two-dimensional diffusion-depletion program. We also find that the three-dimensional nodal code, EPRI-NODE-P, is acceptably verified by comparisons to measured Kewaunee data over three cycles of operation.

Control rod worth values are obtained from K-effectives and control rod positions computed by the nodal code. These are compared to worths obtained by measuring critical boron concentrations at various stages of rod insertion. An uncertainty of approximately 1% is obtained from comparisons of data from the first three Kewaunee cycles but for conservatims, a rod worth reliability factor of 5% is assumed. Although this has been accepted by the staff, it is somewhat smaller than the reliability factors obtained with currently approved design methods. Therefore, we recommend that these rod worth reliability factors be re-evaluated during each physics startup test.

Isothermal temperature coefficients are computed by varying the core average temperature in three-dimensional nodal calculations while holding all other parameters constant. These are compared to isothermal temperature coefficient measurements made with the plant reactivity computer. Based on these comparisons we conclude that the WPS ARMP model predicts the isothermal temperature coefficient with a reliability of $\pm 5.7 \times 10^{-5}$ $\Delta k/k$ per °F when the appropriate bias is included. This represents a 95% probability at the 95% confidence level that the measured isothermal temperature coefficient will be bounded by the predicted value.

The three-dimension nodal code is used to calculate power coefficients as a function of power and exposure. The Doppler coefficient is the calculated by removing the moderator temperature coefficient component from the power coefficient. However, the uncertainty in the measurement of the Doppler coefficient with the plant reactivity computer is too large to quantify a reliability factor and, therefore, a value of 10% is defined by WPS. This is acceptable since it is consistent with currently approved design methods.

The spectral code, EPRI-CELL, produces initial nuclide concentrations, depletion and fission product chain data, and tables of microscopic and macroscopic cross-sections varying with burnup. Based on the good agreement between isotopic compositions calculated by EPRI-CELL and spent fuel isotopic data from Yankee Core 1 and Saxton Core 2, we conclude that the method used to determine isotopic compositions is acceptable.

Comparisons to measured data spanning the first three cycles of Kewaunee operation are used to determine the uncertainties applicable to nodal power distributions. Since the reactor power distribution is not directly observable, the WPS ARMP model has been used to calculate the actual incore detector signals in each of the instrumented locations. Nodal calculations were compared to nineteen separate flux maps representing unrodded, ejected, and dropped rod configurations as well as hot zero power and full power operation. Agreement for both the unrodded and rodded configurations is consistent with that obtained from currently approved design methods.

The uncertainty associated with the calculations of the peak-to-average fuel pin power in each assembly is evaluated by comparisons with experiments conducted in the KRITZ high temperature critical facility in Sweden. These experiments were performed with PWR lattices containing water holes and involved a combination of UO_2 and mixed oxide rods representative of local high flux regions as well as various degrees of core burnup. The uncertainty of PDQ7 with respect to experiment is approximately 2% which is well within the accepted range obtained by currently approved design methods.

The nuclear heat flux hot channel factor ($F^n{}_Q$) is computed by multiplying peak nodal values from the three-dimensional nodal results by the two-dimensional PDQ7 pin-to-box ratios. The 95/95 confidence level reliability factors for F_Q are computed by axial level, ranging from 7.7% at the core midplane to 16.5% at the core top. We find these reliability factors to be acceptable based on comparisons with the uncertainties which have been obtained with other currently approved design methods.

The nuclear enthalpy rise hot channel factor ($F^n_{\Delta H}$) is computed by multiplying the EPRI-NODE-P assembly average power values and the PDQ7 peak pin-to-box ratios. The reliability factor is 5.1% and is acceptable and consistent with values obtained from currently approved design methods.

Evaluation Procedures

We have reviewed the report within the guidelines provided by Section 4.3 of the Standard Review Plan. Included in our review was the description of the experimental data base, the calculations performed, and the comparisons made to support the conclusion that the WPS ARMP computer model is adequate to calculate steady-state physics parameters for Kewaunee reload cores.

Conclusion

We have reviewed the ARMP reactor physics methods used by WPS and benchmarked against Kewaunee measurements over the first three cycles and find them acceptable to be used in Kewaunee safety-related calculations of those quantities described above provided that the identical methods are used that were used in the ARMP documentation.

We also find the detailed discussion and the revised derivation of the uncertainty and reliability associated with each physics parameter acceptable.

We strongly recommend continuation of the WPS monthly core performance reviews which provide comparisons of measurements to model results in order to provide continuing assurance of the model applicability. We also recommend that the control rod worth and Doppler coefficient reliability factors be re-evaluated using the results of each physics startup test since they are somewhat smaller than those obtained with currently approved methods.

The report may be referenced in licensing submittals by WPS for the Kewaunee reactor.