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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT ENEAD-02-NP

"VERIFICATION OF CECOR COEFFICIENT METHODOLOGY FOR

APPLICATION TO PWRs OF THE ENTERGY SYSTEM"

ENTERGY OPERATIONS, INC.

## 1. INTRODUCTION

In a letter of September 23, 1994, from F. W. Titus to the U.S. Nuclear Regulatory Commission (NRC), Entergy Operations, Inc. (EOI) submitted Topical Report ENEAD-02-NP, Revision 0 for NRC review (Ref. 1). The report describes the methodology used at EOI to determine the library coefficients and the resultant reliability factors associated with the Entergy CECOR core power distribution monitoring computer program (Ref. 2). CECOR is a computer program that synthesizes detailed three-dimensional fuel assembly and peak fuel pin power distributions from fixed incore detector signals.

Presently, EOI provides cycle specific data libraries to Arkansas Nuclear One, Unit 2 (ANO-2) and the Waterford Steam Electric Station, Unit 3 (WSES-3) for the CECOR core power distribution monitoring program based on the NRC approval of Topical Report MSS-NA3-P, "Verification of CECOR Coefficient Methodology for Application to Pressurized Water Reactors of the Middle South Utilities System" (Ref. 3). The CECOR libraries in MSS-NA3-P were based on using the PDQ and EPRI-NODE-P computer codes. In ENEAD-02-NP, Revision 0, EOI proposes to use the design computer codes CASMO3 and SIMULATE3 to generate libraries for CECOR at ANO-2 and WSES-3.

## 2. TOPICAL REPORT SUMMARY

Section 1.0 gives a general introduction to the purpose of the topical report. Section 2.0 describes the incore instrumentation for ANO-2 and WSES-3. Section 3.0 describes the algorithms used by CECOR to synthesize the three-dimensional power distribution from the incore detector readings and the coefficient library. Section 4.0 describes the generation of the coefficient libraries from data generated from the EOI reactor physics methods described in ENEAD-01-P, Revision 0, "Qualification of Reactor Physics Methods for Application to Pressurized Water Reactors of the Entergy System" (Ref. 4). Section 5.0 provides a quantification of CECOR uncertainties using EOI generated libraries.



ENCLOSURE

3. TOPICAL REPORT EVALUATION

The NRC staff has reviewed the information presented in ENEAD-02-NP, Revision 0, with regard to the analytical methods and the statistical methods. The data base used to establish the comparison between measurement and calculation in determining the basic measurement uncertainty was examined. The CECOR program synthesizes three-dimensional power distributions from fixed incore detector readings. The signals from the five axially spaced detectors in each string are converted to powers. Next, coupling coefficients are used to calculate pseudo-detector powers in uninstrumented assemblies or assemblies with failed detectors. Then, using a five term Fourier fit, an assembly axial shape is constructed based on the five detector powers. Calculation of the maximum 1-pin assembly peaks are done using 1-pin peaking library coefficients, which are functions of burnup, control rod position, and axial detector location. All of the information necessary to generate the CECOR data library comes from three-dimensional, quarter core, full power, nodal code depletion calculations and lattice physics calculations.

The determination of the CECOR uncertainties consists of three components defined in the original INCA/CECOR power peaking uncertainty report (Ref. 5): the box (assembly) power measurement uncertainty, the power synthesis uncertainty, and the pin peaking calculational uncertainty. Since the nodal code is capable of producing three-dimensional pin peaking distributions, the pin peaking synthesis uncertainty mentioned in Reference 5 is now automatically included in the power synthesis uncertainty.

The box power measurement uncertainty is the uncertainty associated with the measurement of power at the five detector levels. It includes uncertainties in the measured signals in instrumented locations and the uncertainties in the signal-to-power conversion. It is determined by comparing CECOR measured instrument powers using actual measured detector signals to powers calculated by the nodal code. In all, nine cycles of data for ANO-2 and six cycles of data for WSES-3 were used in the analysis. The ability of SIMULATE3 to perform three-dimensional calculations results in an improvement in the calculation of the signal-to-power conversion factor.

The power synthesis uncertainty is the uncertainty associated with the construction of pin powers from detector powers. It includes uncertainties associated with coupling coefficient synthesis, pin-to-box synthesis and axial fitting. The power synthesis uncertainty also includes uncertainty associated with the number of operable detectors. Multiple CECOR calculations were performed with 0, 12.5, 25, 37.5, and 50% of the detectors assumed to fail randomly. In response to the staff's concern (Ref. 6), EOI stated that the uncertainty based on the random detector failure pattern used in ENEAD-02-NP is conservative because; (1) the 95%/95% reliability factor based on the uncertainty from random failures bounded all "worst allowable" failure patterns, and (2) data from 15 cycles of operation of ANO-2 and WSES-3 have shown that detectors do basically fail in a random pattern during actual operation. Based on this, we find the detector failure assumptions used in ENEAD-02-NP acceptable.

The pin peaking calculational uncertainty is the uncertainty associated with the nodal code calculation of pin-to-box peaking factors. These were based on SIMULATE3 comparisons to ANO-2 and WSES-3 cores as well as critical experiments and documented in the physics methodology report which has been reviewed and approved by the NRC (Ref. 4). The benchmark calculations contained boron carbide, erbium and gadolinium burnable absorbers. Since the erbium cores showed a slightly larger uncertainty than the other absorbers, the erbium uncertainty (1.261%) was used in the overall CECOR uncertainty for conservatism.

In order to determine a reliability factor for the random error in the total peaking factor ($F_q$), integrated radial peaking factor ($F_r$), and planar radial peaking factor ($F_{xy}$), the above described three uncertainty components were combined statistically. The methods used were the same as those used in Reference 3. The overall uncertainties are given in Table 5.5-7 of ENEAD-02 and are such that there is a 95% probability that at least 95% of the time, $F_q$, $F_r$, and $F_{xy}$ values will be less than the value derived from the measurement with accuracies ranging from 4.10%, 3.32% and 3.80%, respectively, for no failed detectors, to 4.20%, 3.76% and 4.05%, respectively, for 50% detector failures. These reliability factors are based on the results from either the ANO-2 or the WSES-3 data, whichever were more conservative, and are therefore, acceptable.

## 4. CONCLUSIONS

Based on our review of the experimental data base, the calculations performed, and the methods used to determine the components of uncertainty and the combination of these components into overall uncertainties, we find the methodology described in ENEAD-02-NP acceptable for use by EOI for the ANO-2 and WSES-3 plants. In addition, we find the following overall measurement uncertainties at the one-sided 95/95 probability/confidence level are acceptable:

| | Measurement Uncertainty | | |
|---|---|---|---|
| % Detector Failures | $F_{xy}$ | $F_r$ | $F_q$ |
| 0 | 3.80 | 3.32 | 4.10 |
| 12.5 | 3.88 | 3.35 | 4.09 |
| 25.0 | 3.93 | 3.45 | 4.14 |
| 37.5 | 3.94 | 3.56 | 4.17 |
| 50.0 | 4.05 | 3.76 | 4.20 |

## 5. REFERENCES


(1) Letter from F. W. Titus (EOI) to Document Control Desk (NRC), Request for Review of Entergy Topical Report Verification of CECOR Coefficient Methodology for Application to Pressurized Water Reactors of the Entergy System, (ENEAD-02-NP, Revision 0), dated September 23, 1994.

(2) NPSD-103-P, "CECOR 2.0 General Description, Methods and Algorithms, Combustion Engineering, June 1980.

(3) Letter from T. M. Novak (NRC) to R. W. Leddick, Verification of CECOR Coefficient Methodology for Application to Waterford 3, August 30, 1985.

(4) Safety Evaluation by the Office of Nuclear Reactor Regulation, Topical Report ENEAD-01-P, Rev. 0, "Qualification of Reactor Physics Methods for Application to Pressurized Water Reactors of the Entergy System," September 26, 1995.

(5) CENPD-153-P, Rev. 1-P-A, "INCA/CECOR Power Peaking Uncertainty," Combustion Engineering, May 1980.

(6) Letter from F. W. Titus (EOI) to Document Control Desk (NRC), Request for Additional Information Regarding Topical Report Verification of CECOR Coefficient Methodology for Application to Pressurized Water Reactors of the Entergy System, (ENEAD-02-NP, Revision 0) (TAC Nos. M90609 and M90626), February 2, 1995.

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