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SUBJECT: Provides response to request for addl info re Topical Rept DPC-NE-1004, "Nuclear Design Using CASMO-3/SIMULATE-3P."

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January 23, 1992

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Subject: McGuire Nuclear Station
Docket Numbers 50-369 and -370
Oconee Nuclear Station
Docket Numbers 50-269,-270, and -287
Catawba Nuclear Station
Docket Numbers 50-413 and -414
Topical Report DPC-NE-1004: Response to Request for Additional Information

By letter dated January 26, 1990, Duke Power submitted Topical Report DPC-NE-1004, "Nuclear Design Using CASMO-3/SIMULATE-3P." By letter dated December 6, 1991, the NRC responded with a set of questions pertaining to the Topical Report.

Attached are the responses to those questions.

If there are any questions, or if we may be of further assistance in your review, please call Scott Gewehr at (704) 373-7581.

Very truly yours,

H. B. Tucker

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DPC-NE-1004
Response to Request for Additional Information

1. Question: Identify the "data based on ENDF/B-V" used in the CASMO-3 calculation, as stated in Section 2.1(a), and the data based on ENDF/B-IV.

Answer: The majority of the data in the CASMO-3 library is based on ENDF/B-IV. The data selected from ENDF/B-V which is of primary importance includes the Xenon-135 yields and fission spectra data for U-235 and Pu-239. Additionally, the resonances for U-238 have been adjusted to agree with Hellstrand's resonance integral measurements.

2. Question: When is the 70 energy group cross-section library used in the CASMO-3 calculation and when is the 40 group library used?

Answer: All of the calculations used as the basis for DPC-NE-1004 utilized the 40 energy group library. However, DPC would like to reserve the right to use the 70 group library. As noted in the response to question #11, CASMO-2 is currently used to generate ratios of Rhodium detector reaction rates to the power in the 8 surrounding fuel pins. This is done using the 69 group library for CASMO-2. It may, likewise, be necessary to use the 70 group library with CASMO-3 when generating these ratios. It would be expected that use of the 70 group library would yield as good or better results based on the additional detail of the calculations.

3. Question: Identify the three-dimensional calculations which DPC will perform using the SIMULATE-3P sequence and the EPRI-NODE-P sequence. How many axial nodes will be used in either one?

Answer: DPC intends to use SIMULATE-3P as a substitute for PDQ and be supplemented by EPRI-NODE-P similarly to the descriptions provided in references 1, 2, 3, 6, 8, and 9 or to utilize SIMULATE-3P as a substitute for any EPRI-NODE-P as well as PDQ calculations. The applicable uncertainties for the particular code selected will then be applied as provided in section 5.0.

The SIMULATE-3P models for all units utilize 12 axial fuel nodes plus one top and one bottom reflector node. The EPRI-NODE-P model for McGuire and Catawba utilizes 18 axial fuel nodes. For Oconee, the EPRI-NODE-P model utilizes 16 axial fuel nodes. The increased number of axial nodes in the EPRI-NODE-P models is required because the program does not model the intranodal peaking which SIMULATE-3P includes.

4. Question: Are any adjustments made in the SIMULATE-3P model in order to improve comparisons with measurements?

Answer: There are no adjustments made to the SIMULATE-3P model to enhance the comparisons.

5. Question: Have any adjustments been made in any of the SIMULATE-3P models (BOC, HZP, ARO) used in the determination of the critical boron concentration for the reactor cores listed in Table 3-1? If so, please explain.

Answer: No adjustments have been made to the SIMULATE-3P model for HZP conditions. The cross-section libraries utilized for HFP conditions also cover the range down to HZP.

6. Question: Have any cycle-to-cycle adjustments been made in the SIMULATE-3P models of the reactor cycles listed in Tables 3-2 through 3-6 and Figures 3-6 to 3-14, other than those changes due to operating conditions?

Answer: No.

7. Question: Explain the observed SIMULATE-3P HFP critical boron concentration underpredictions for Catawba Unit 2, Cycle 3, Oconee Unit 2, Cycles 9 and 10 and overpredictions for the McGuire Unit 2, Cycles 2 through 5.

Answer: A general explanation of possible causes for mispredictions of critical boron concentrations has been provided in response to question #12. The results for Catawba Units 1 and 2 are very consistent and demonstrate consistent trends with McGuire Unit 2, with the initial cycle having a more negative result than the reload cycles. The McGuire Unit 2 results appear to have a bias as compared to the Catawba units with the initial cycle having a small overprediction for McGuire Unit 2 and a small underprediction for Catawba Units 1 and 2. Because the same fuel types and similar models are used for the McGuire and Catawba units, this bias may be attributed to plant specifics such as as-built plant and fuel differences. The results for Oconee Units 2 and 3 show very consistent trends in their underpredictions. The difference in trends between the B&W versus Westinghouse units is indicative of differences due to plant design, plant procedures, fuel designs, fuel vendors, etc. In the later cycles modelled for Oconee Units 2 and 3 there were some difficulties encountered with fouling of the Venturi tubes which are used in measuring the power level. This may account for the small changes observed in the Oconee Unit 2, Cycle 9 and 10 results. However, because the error in the measured power levels is unknown, the quantitative effect of the fouling cannot be determined. Please note that there were no HFP boron comparisons provided for Catawba Unit 2, Cycle 3 as the cycle had not yet completed operation when the benchmark calculations were

performed. Subsequent discussions with the NRC representative identified that the question should have referred to Catawba Unit 2, Cycle 1 instead of Cycle 3.

8. Question: How is the dependence of the generic ratios of power to detector reaction rates (used in the conversion of corrected signals) on parameters such as moderator temperature, exposure, and control accounted for?

Answer: Refer to the answer for question #11.

9. Question: Describe the method of selection of albedos and/or reflector constants used in the EPRI-NODE-P model. Are these constants changed from cycle to cycle?

Answer: The axial albedos employed in EPRI-NODE-P were selected to obtain axial offsets and normalized axial peaks which are consistent with the SIMULATE-3P calculations. The radial albedos in EPRI-NODE-P were selected to obtain peripheral assembly powers consistent with SIMULATE-3P. The axial albedos remain the same from cycle to cycle and are only likely to change if fuel assembly/burnable poison designs are changed. The radial albedos are adjusted every cycle to match SIMULATE-3P.

10. Question: Describe how the measured fission chamber signals are used in the derivation of the relative assembly powers. Describe all corrections/adjustments made to the measured signals to determine the local power.

Answer: The movable incore fission chambers are intercalibrated for each power distribution measurement. The signals are therefore normalized based on this intercalibration. Sets of predicted assembly and peak pin powers versus predicted fluxes in the instrument location from PDQ are used in conjunction with detector cross sections to convert the normalized signals to relative powers. Sets of data(theoretical factors) are provided as a function of cycle burnup and control rod presence. The basic equation used is:

$$P(\text{measured}) = \frac{P(\text{calculated})}{RR(\text{calculated})} * RR(\text{measured})$$

where: P(measured) = measured relative power
P(calculated) = predicted power from PDQ
RR(measured) = measured reaction rate
RR(calculated) = predicted relative reaction rate

When PDQ is used to generate the theoretical factors, the predicted relative reaction rates are calculated using the fluxes from PDQ and a set of predetermined detector cross-sections. When SIMULATE-3P is used instead of PDQ, the relative reaction rates may be calculated directly by SIMULATE-3P.

11. Question: Why are the rhodium detector signals corrected for a specific core configuration? How is this correction made? How are the signals corrected for rhodium depletion and background current?

Answer: The corrected signals are obtained by first subtracting the background signal from the raw signal. The background signal is measured by a separate lead wire included in each detector string. The background-corrected signal is then corrected for depletion based on the amount of spent charge over the lifetime of the detector. This spent charge is converted to a depletion correction factor and the signal is corrected back to what would be obtained with a fresh detector based on calculated detector signals versus percent depletion.

The corrected signals are converted to relative assembly powers by means of precalculated ratios of the power in the surrounding 8 fuel pins to detector reaction rates multiplied by predicted assembly to 8 fuel pin powers. The dependence of the flux distribution within an assembly on the moderator temperature, control rod presence, fuel enrichment, and exposure influences these ratios. Therefore, the ratios of reaction rates to power are generated for a variety of conditions and included in a database. The corrected signals are converted into relative power based on the ratio appropriate to the conditions of the measurement.

Currently, the ratios of detector reaction rates to the power in the surrounding 8 fuel pins is calculated with CASMO-2 at predetermined burnups, moderator temperatures, enrichments, control rod conditions, etc. Likewise, the ratios of the power in the assemblies to the 8 pins surrounding the detector are calculated as a function of burnup with PDQ. DPC intends to utilize CASMO-3 and SIMULATE-3P for this purpose in the future.

12. Question: Explain the trend with exposure of the boron difference for Catawba Unit 1, Cycles 1, 2, and 3, and Oconee Cycles 7 through 10. What is causing the significant boron overprediction in the early part of Catawba Unit 1, Cycle 3? Please explain.

Answer: There are a variety of explanations available for the noted boron differences. Among these are the uncertainties associated with the T_{ave} programs of the individual plants, the heat balance procedure for determining thermal power, the "as-built" Uranium and burnable poison loadings, variability of soluble boron enrichment and B_{10} depletion, and non-

equilibrium reactor conditions. The approach used in performing these benchmarks was intended to reflect the method which would be used to perform reload design analysis. Many of the above factors are not known in advance. Therefore, nominal values were used to set up the models employed in the benchmarks. In practice, where consistent biases are observed through several cycles the biases would be applied to the calculated results. However, for the purpose of the benchmarks no biases have been applied.

13. Question: There appears to be a systematic overprediction of the boron letdown in the early part of Cycles 3, 4, and 5 of McGuire Unit 2. Please explain.

Answer: One of the possible causes of these overpredictions lies in the specifications for the B_{10} content of the boric acid. This is ordered to a specification of 19.9 ± 0.3 a/o B_{10}. The content assumed in the model is 19.83. This variability could account for 15-20 PPMB of the anomaly shown at the beginning of the mentioned cycles. Other possible causes for the overpredictions have been listed in the response to question #12.

14. Question: What is the cause of the large percent differences between the measured and SIMULATE-3P calculated BOC, HZP control rod worths of Catawba Unit 1, Cycle 4 (Table 3-7) and McGuire Unit 2, Cycles 2, 3, and 4 (Table 3-9)?

Answer: For the cycles identified, large percentage differences (>10%) are primarily associated with relatively small worths, and are actually small differences in the absolute sense. For those cases where large differences were identified only one case resulted in more than $\pm$ 100 pcm (Catawba 1 Cycle 4, Control Bank B). This case utilized the rod swap measurement technique and resulted in an error of 114 pcm. Based on past experience and known uncertainties with the rod swap test, the acceptance criteria as approved in reference 6 is that the absolute difference be $\leq$ 30% or $\leq$ 200 pcm, whichever is greater. All of the cases identified easily meet this criteria. A better indication of the model's accuracy may be obtained by evaluating the comparisons to measurement in the cases where boron dilution is used to measure the rod worths. This is the case for all of the Catawba 1 Cycle 1 and McGuire 2 Cycle 1 rod worths. This method was also used to measure the reference bank worth (the largest single bank worth) for all of the remaining Catawba and McGuire cycles. For those cases where the boron/dilution method is used, no differences > 10% were observed.

15. Question: No comparisons are given in Table 3-14 of measured and calculated EOC HFP isothermal temperature coefficients for McGuire Unit 2,

Cycle 1, Catawba Unit 1, Cycle 4 and Catawba Unit 2, Cycle 3. Please discuss.

Answer: At the time the benchmarks were performed and the topical written, Catawba 1 Cycle 4 and Catawba 2 Cycle 3 were still in operation and the EOC ITC measurement had not yet been made. As stated in section 3.3 the McGuire 2 Cycle 1 measurement utilized a different technique than the other cycles which are included. The results from this technique were considered to be suspect and prompted the change in measurement technique.

16. Question: Provide the following design data for the fuel assemblies for which comparisons of calculated and measured relative radial assembly powers are presented in Figures 3-6 through 3-14: fuel pin layout, range of enrichment and burnable poison loading, and core average exposure. Discuss to what extent these fuel designs cover the intended DPC applications. Is there any correlation between the specific fuel designs and the observed large calculation-to-measurement differences?

Answer: For these specific figures the range of enrichment was from 3.10 to 3.40 w/o U_{235} initial enrichment, the burnable poison loadings ranged from 0.20 to 1.10 w/o B4C for Oconee and for Catawba/McGuire used 4 or 8 finger BPs at 13.5 w/o B4C, and the core average exposures ranged from 11.726 - 25.715 GWD/MTU. The applicable fuel pin layouts are shown below:

Catawba/McGuire

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 3 1 1 3 1 1 3 1 1 1 1 1 1
1 1 1 3 1 1 1 1 1 1 1 1 3 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 3 1 1 3 1 1 3 1 1 3 1 1 3 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 3 1 1 3 1 1 2 1 1 3 1 1 3 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 3 1 1 3 1 1 3 1 1 3 1 1 3 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 3 1 1 1 1 1 1 1 1 3 1 1 1 1
1 1 1 1 3 1 1 3 1 1 3 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

Oconee

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 3 1 1 1 3 1 1 1 1 1
1 1 1 3 1 1 1 1 1 1 1 3 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 3 1 1 3 1 1 1 3 1 1 3 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 3 1 1 3 1 1 1 3 1 1 3 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 3 1 1 1 1 1 1 1 3 1 1 1
1 1 1 1 1 3 1 1 1 3 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

where: 1 = Fuel Pin Location
2 = Instrument Tube Location
3 = Guide Tube/Control Rod/BP Location

Note that, as stated in section 3.4(b), these figures are only representative comparisons from the most recently analyzed cycle at each station. The cycles used to generate the database for reliability factors includes enrichments from 1.6 to 3.6 w/o U_{235}, Oconee BPs from 0.0 to 1.1 w/o B4C, Westinghouse BPs with 0, 4, 6, 8, 9, 10, 12, 15, 16, and 20 fingers (with either 13.5 w/o B4C or 12.5 w/o B2O3 for WABA and Pyrex absorbers, respectively), and core average exposures from 0.0 to 25.714 GWD/MTU. DPC anticipates that this model would be applied up to enrichments of about 4 w/o (or greater if future fuel rack limits permit), BP loading of near 1.4 w/o B4C, BP finger arrangements of up to 24 fingers, and core average exposures of near 30 GWD/MTU. The wide range of data examined provides a high degree of confidence that the model will perform consistently under these conditions.

No correlation has been determined between specific fuel designs and the "observed large calculation-to-measurement differences". Note that the differences shown are given as percentages and that they demonstrate accuracies which are as good as or better than what are typically demonstrated by vendor or other utility comparisons.

17. Question: Has DPC performed pin power distribution benchmark comparisons with CASMO-3 to justify the use of a pin wise power uncertainty of 2 percent. How is conservatism ensured in the selection of this value?

Answer: DPC has not performed benchmarking of CASMO-3 pin power distributions to critical experiments. The reference 5 submittal by Yankee Atomic Electric Co. did include comparisons of SIMULATE-3P pin power distributions to critical experiments. The ability of CASMO-3 to calculate these distributions is a part of the uncertainty in the SIMULATE-3P predictions. Since SIMULATE-3P was quantitatively benchmarked in reference 5, DPC did not consider it necessary to repeat this benchmarking.

DPC has performed comparisons to critical experiments using CASMO-2 as identified in reference 1. As part of the reference 3 submittal DPC also provided calculations supporting an uncertainty of 1% using the EPRI-CELL/PDQ07 code sequence. However, the NRC at that time indicated that a more conservative value of 2% should be utilized as a reliability factor. Since the reference 5 submittal demonstrated, "SIMULATE-3 to predict pin-by-pin distributions within 1%", it is expected that similar results would be obtained if DPC did a similar benchmarking. Therefore, an uncertainty of

2% is considered to be conservative and would be consistent with the minimum value which the NRC has found to be acceptable for DPC in the past.

18. Question: Justify the assumption that the data from McGuire/Catawba and Oconee are sufficiently similar to allow a statistical combination to determine calculational uncertainty parameters.

Answer: McGuire and Catawba are sister Westinghouse 4-loop plants which utilize the same fuel design and similar NSSS systems. The data for McGuire/Catawba has not been combined with that from Oconee in generating the reliability factors. Separate reliability factors for the Westinghouse units and the B&W units have been provided in section 5. Data was tabulated for all units combined(Westinghouse and B&W) and each individual cycle in section 3 for demonstrative purposes only.

19. Question: In the McGuire/Catawba and Oconee data base, why is N for the radial NODE-P data smaller than its corresponding value for the SIMULATE-3P data? Have any NODE-P or SIMULATE-3P data been dropped from the data base? If so, justify this deletion.

Answer: As stated in section 4.2(b), the reliability factors are based on comparisons of calculated and measured values only where both values are $\geq$ 1.0. This is based on the assumption that the primary importance of these factors is related to conservatively calculating the limiting peak powers in the core. Because this is a comparison of relative power distributions, all axial data will have values which are $\geq$ 1.0. However, radial comparisons were included in the database for cases where the measured value was $\geq$ 1.0 only if the calculated value for the particular model was also $\geq$ 1.0. This resulted in there being a different number of valid data points for the different models.