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CEN-157(A)-NP

RESPONSE TO QUESTIONS ON DOCUMENTS SUPPORTING THE ANO-2 CYCLE 2 LICENSE SUBMITTAL

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LEGAL NOTICE

CEN-157(A)-NP

RESPONSE TO QUESTIONS ON DOCUMENTS SUPPORTING THE ANO-2 CYCLE 2 LICENSE SUBMITTAL

Abstract

This report contains some of the responses to NRC questions on CEN-143(A)-P and CEN-139(A)-P which were given to Arkansas Power and Light and Combustion Engineering, Inc. at a meeting in Bethesda, Maryland and by subsequent telecopy. These questions were variously identified as questions A1 through A-28 and then 492.1 through 492.29. (One question was added in this latter list.) This report does not contain responses to questions 492.23 (A-24) or 492.24 (A-25), which will be supplied separately.

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1.0 Introduction

C-E's reports CEN-143(A)-P and CEN-139(A)-P have been submitted on the Arkansas Nuclear One-Unit 2 docket in support of the Cycle 2 License Submittal. NRC questions about these two reports were given to Arkansas Power and Light and Combustion Engineering, Inc. at the March 26, 1981 meeting in Bethesda, MD. These questions were then identified as questions A-1 through A-28. Subsequently, a revised list of questions was transmitted by telecopy. That list contained one additional question, reordered the resulting set of questions and redesignated them as 492.1 through 492.29.

This report contains answers to all of the questions except the two designated 429.23 (A-24) and 492.24 (A-25). They will be answered in a separate submittal.

2.0 Responses to NRC Questions on CEN-143(A)-P and CEN-139(A)-P

Question 492.1 (A-1)

It was understood that the CETOP code was developed as a C-E Thermal On-Line Program. However, the Appendix A of CEN-143 refers to the CETOP as a design thermal margin program. Is the CETOP used as a design analysis tool for the ANO-2 core?

Answer

CETOP (also referred to as CETOP-D) was used as the design thermal margin code for ANO-2 Cycle 2. The CETOP-D code is used to derive and verify the CPC on-line thermal margin algorithm CETOP2.

Question 492.2 (A-3)

Provide a complete description of the CETOP program methodology, algorithm and its usage for ANO-2 Cycle 2 reload.

Answer

A complete description of the CETOP (CETOP-D) programming methodology was provided in response to first round questions on CEN-139(A)-P. The description of the CETOP2 algorithm was provided in Appendix B to CEN-143(A)-P. Its usage for ANO-2 Cycle 2 was described in Section 6.1 of the Reload Analysis Report and in CEN-143(A)-P, Section 2.1.

Question 492.3 (A-4)

In the CETOP program, the transport coefficients of pressure, enthalpy and axial velocity associated with turbulent interchange are used in conservation equations. Describe how these coefficients are obtained. Provide sensitivity studies of DNBR vs. these coefficients. What are the values of these coefficients used in CETOP-2?

Answer

Transport coefficients are used to adjust calculations involving a lumped channel for the fact that coolant properties associated with turbulent interchange and diversion crossflow are not the lumped channel average values. The application of the transport coefficients to the conservation equations is described in References 1 and 2.

REFERENCES

1. C. Chiu, et al., "Enthalpy Transfer Between PWR Fuel Assemblies in Analysis by the Lumped Subchannel Model," Nuclear Engineering and Design, 53, pp. 165- 186, (1979).

2. "CETOP-D Code Structure and Modeling Methods,"(Responses to First Round Questions on the Statistical Combination of Uncertainties Program, CEN-139(A)-P), March 1981.

The pressure and velocity transport coefficients will be discussed first. These coefficients were shown in Reference 1 to have no significant effect on the enthalpy, and therefore, on the DNBR, of the hot channel. Further evidence of the insensitivity of the DNBR to these values is given in Table 1. The values of these coefficients used in CETOP-D and CETOP-2 are typical values calculated from TORC subchannel results. Table 2 provides the values used in CETOP-D and CETOP-2 for ANO-2, Cycle 2. The velocity transport coefficient is [ ] This is due to the simplifying assumption that the mass velocity in the buffer channel equals the mass velocity in the hot channel. This simplification reduces the execution time of the algorithm. Any errors resulting from this simplification are covered by the algorithm penalty factor discussed in response to question 492.15.

The enthalpy transport coefficient has been shown to have a significant effect on the hot channel enthalpy (see Reference 1 and Table 1). In CETOP-D an algorithm is used to calculate an enthalpy transport coefficient at each axial level. This method is described in Reference 2. In CETOP-2 a constant value is used for the enthalpy transport coefficient in order to keep the algorithm execution time to a minimum. The value for ANO-2 Cycle 2 is given in Table 2. [ ]

Any errors resulting from this simplification are covered by the algorithm penalty factor discussed in response to question 492.15.

The use of transport coefficients in the CETOP programs permits substantial simplification while retaining high accuracy. The tuning of the CETOP-D model to TORC over the entire range of operating conditions (See Reference 2) assures that CETOP-D gives results which are conservative relative to TORC. The CETOP-2 algorithm penalty factor provides a high degree of assurance that CETOP-2 results are conservative relative to CETOP-D despite approximations such as the use of a constant enthalpy transport coefficient or the simplification in the treatment of the buffer channel.

Question 492.4 (A-5)

In the 3-D lumped subchannel modelling, how are the hot assembly and hot channel selected? How is it assured that the selected hot channel is the hottest channel that has minimum DNBR? During an operating transient, how does the model handle the situation where the hottest channel may move to another channel?

Answer

When comparing CETOP-D to detailed TORC for a given range of operating conditions the location of the hot assembly and hot channel is important only in the detailed TORC model. The selection of the hot assembly and hot channel in detailed TORC is explained in Section 4 of CENPD-161-P. As a result of the comparison between CETOP-D and detailed TORC, the inlet flow factor for the hot assembly in CETOP-D is adjusted to yield conservative or accurate DNBR predictions relative to detailed TORC. (The inlet flow factor in S-TORC was adjusted in the same manner, as described in CENPD-161-P).

TABLE 1

DNBR Sensitivity to Transport Coefficients in CETOP-D
(Response to Question 492.3)

VALUE OF TRANSPORT COEFFICIENT	DNBR* SENSITIVITY TO N_H	DNBR SENSITIVITY TO N_U	DNBR SENSITIVITY TO N_P
[			]

All sensitivities are relative to a base DNBR of 2.1657

This DNBR was obtained using the following values:

Pressure 2250 psia
Inlet Temperature 55?^{o}F
Core Flow 100% of nominal
Power 100% of rated

N_H = self generated by CETOP-D (enthalpy transport coefficient)
N_U = [ ] (velocity transport coefficient)
N_P = [ ] (pressure transport coefficient)

* The sensitivity of the DNBR to N_H compares DNBR's using constant N_H values to the self-generated case.

TABLE 2

ANO-2 Cycle 2 CETOP-D/CETOP-2
Transport Coefficient Values
(Response to Question 492.3)

TRANSPORT COEFFICIENT	CETOP-D VALUE	CETOP-2 VALUE
ENTHALPY (N_H)	CALCULATED INTERNALLY	[ ]
VELOCITY (N_U)	[ ]	NOT APPLICABLE
PRESSURE* (N_P)	[ ]	[ ]

* Note that in the code the pressure transport coefficient is given as C_N =
[ ]

This adjusted CETOP-D model is then independent of the actual location of the hot assembly or hot channel within the core since it has been tuned against the hottest assembly in detailed TORC that could be limiting in DNBR. For transients in which the hottest channel may move, detailed TORC models used for the tuning of CETOP-D cover all possible potentially limiting locations of the hottest channel.

Question 492.5 (A-6)

The CETOP code uses a prediction-correction method, as opposed to the iterative method used in the TORC, to solve the finite difference equations of the conservation laws. How is it guaranteed that there is no instability problem?

Answer

The prediction-correction method used in the CETOP-D and CETOP-2 codes is a non-iterative one-pass method. Therefore, there are no instability problems related to convergence.

Thousands of cases, covering the entire range of operating conditions, have been run comparing CETOP to TORC. Excellent agreement has always been obtained. Note also that the tuning of the CETOP-D model, discussed in response to questions 492.4 and others, conservatively compensates for any small errors due to the differences in numerical schemes between CETOP-D and TORC.

Question 492.6 (A-7)

The core inlet flow distributions are determined from reactor model experiments for CE type cores. Is the inlet flow split held constant during operating transients?

Answer

The hot assembly inlet flow factor(inlet flow split) is adjusted in CETOP-D to be conservative for all conditions and held constant. This adjusted flow split can be different from the value found at any given assembly location.

For transients in which the inlet flow distribution may change significantly, the CETOP-D model is benchmarked against a detailed TORC model which incorporates the more adverse of the initial and final inlet flow distributions as determined by reactor model experiments. The benchmarking of CETOP-D to detailed TORC is discussed in response to Question 492.7 and the value of the flow split is discussed in response to Question 492.14.

The determination and use of the inlet flow split for CETOP is the same as that described for S-TORC in CENPD-206-P.

Question 492.7 (A-8)

Provide comparison between the CETOP and TORC results that cover the whole spectrum of operating conditions. Provide an assessment of accuracy on the CETOP code. Justify any reduction in scope of this assessment from that provided in the T&H supplement to CENPD-170 with respect to the original CPC software.

Answer

Figure 1 shows the comparison between detailed TORC and CETOP-D for ANO-2 Cycle 2 and other plants. In all cases throughout the range of operating conditions, CETOP-D calculates a DNBR lower than detailed TORC.

CEN-143(A)-P Appendix B Part 2 describes the accuracy assessment for CETOP-2. As discussed in response to Question 492.15, a penalty factor on core power is determined from this accuracy assessment. The scope of the assessment is not less than that provided for CPCTH in CENPD-170-P Supplement 1-P. The range of conditions considered are shown in Figure 2.

Question 492.8 (A-9)

In the CETOP-2, two correlations of curve fits used for void fraction calculations fit the Martinelli-Nelson void fraction model. However, there are discrepancies in the range of applicability of these correlations as shown below:

	QUALITY RANGE OF APPLICABILITY		
Correlation Coefficient	TORC	CETOP-2 Table B-1	CETOP-2 Programming
ALL's	$0.01 < X \leq 0.1$		
ALH's	$0.1 < X < 0.9$		

Which is the right quality range of applicability? What is the pressure range? Justify any simplifying assumptions applied in the CETOP-2 software.

Answer

The values of the quality ranges used in determining the void fraction correlation in CETOP-2 are the [same as those used in TORC.] The values given in Table B-1 and on page B-7 of CEN-143 are incorrect. The correct implementation of the void fraction correlation is given on page B-26 of CEN-143(A)-P.

The pressure range for this correlation is the same as in TORC.

Figure 1

COMPARISON IN MDNBR BETWEEN CETOP-D (TUNED) and DETAILED TORC

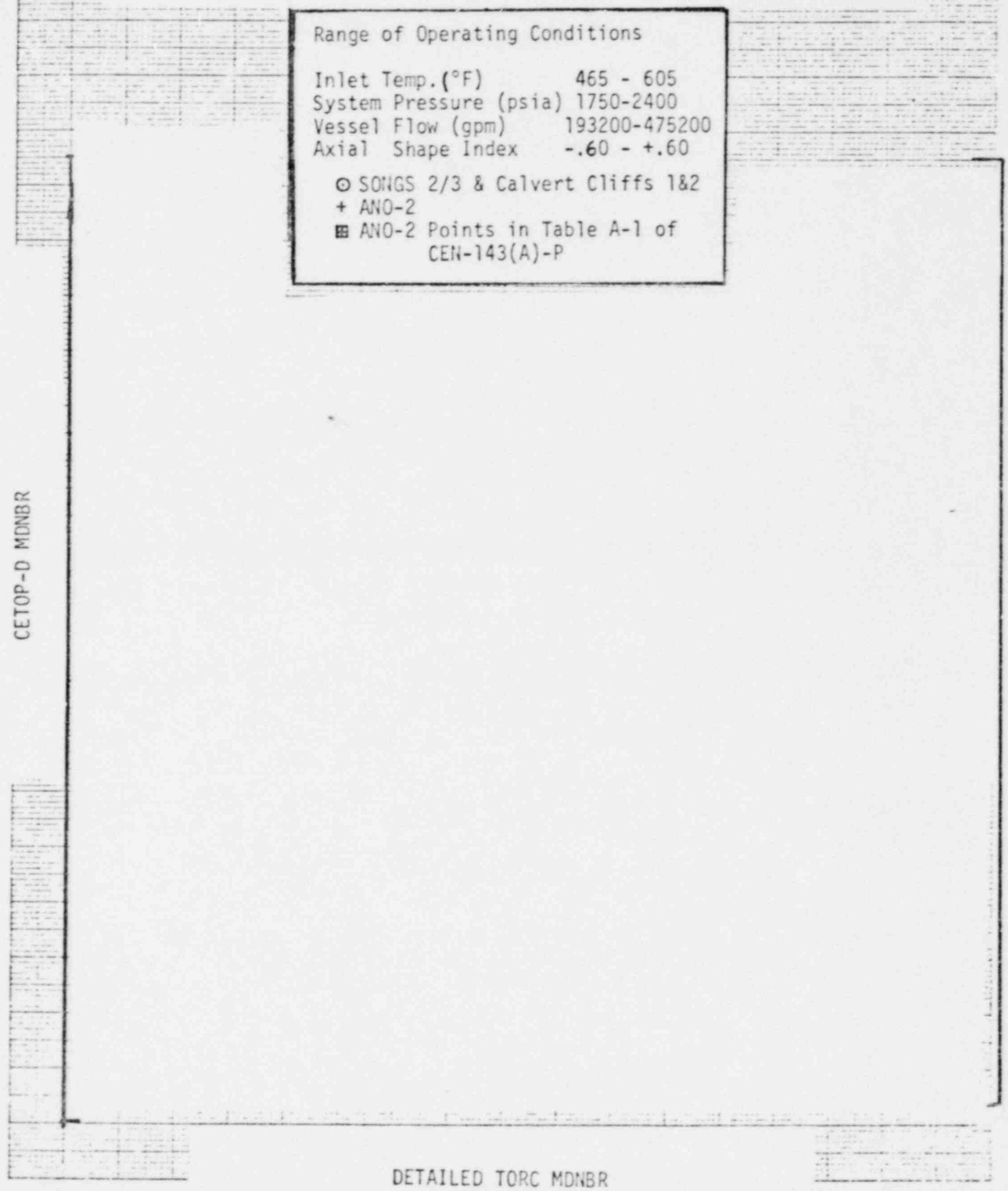


Figure 2

Range of Conditions Considered for
CETOP-2 Accuracy Assessment
for ANO-2 Cycle 2
(Answer to Question 492.7)

Inlet Temperature	• 465°F > T_{IN} > 605°F
Pressure	• 2400 psi > P> 1750 psi
Flow	• 120% > F > 90%
Axial Shape Index	• +.60 > ASI > -.60
DNBR Range	• 2.40 >DNBR > 1.24

Question 492.9 (A-10)

Provide justifications for choosing the Martinelli-Nelson void fraction model over other models such as homogeneous, slip flow or drift flux models. Is subcooled boiling considered?

Answer

For pressures below 1850 psia, the void fraction is given by the Martinelli-Nelson model. This correlation is used in CETOP exactly as in our approved TORC code (CENPD-161-P) and is further discussed in the CETOP-D description provided in response to questions on CEN-139(A)-P.

TORC includes a correlation to calculate subcooled void fractions for information only. The correlation is not used in computing pressure drop or in design DNB analyses.

Question 492.10 (A-11)

What correlation is used for the two-phase multiplier for frictional pressure drop calculations? Provide a comparison of data and the result of your curve fits.

Question 492.11 (A-12)

What correlation is used for the subcooled boiling two-phase multiplier for frictional pressure drop.

Answer

The Sher-Green and Modified Martinelli-Nelson correlations are used to determine the two-phase multipliers for frictional pressure drop calculations during local (subcooled) and bulk boiling conditions. These correlation are applied exactly as in our approved TORC methodology and are discussed in CENPD-161-P and in the CETOP-D description provided in response to questions on CEN-139(A)-P.

Question 492.12 (A-13)

Provide a comparison between the saturated liquid properties and the curve-fit results. What is the range of applicability of pressure?

Answer

In CETOP-D, exactly as in the approved TORC code, fluid properties are based upon a series of subroutines that use a set of curve-fitted equations to describe the fluid properties in the ASME steam tables. Fluid properties are discussed in CENPD-161-P, and in the CETOP-D description provided in response to questions on CEN-139(A)-P.

Question 492.13 (A-14)

In the calculation of core and hot assembly inlet conditions, a flow measurement adjustment term, M_{ERR}, is added to the coolant mass velocity calculation. Is this adjustment in the non-conservative direction? If so, provide justification.

Answer

The flow measurement adjustment term, M_{ERR}, is entered as a negative number if a decrease in the coolant mass velocity is appropriate.

Question 492.14 (A-15)

In the core inlet flow split calculation, the algorithm results in the same value of hot assembly flow saturation factor (FSPLIT) regardless of operating conditions such as ASI, primary pressure and coolant temperature. Justify the value of [ ]

Answer

CETOP-2 contains the capability for entering two flow split values for two operating ranges. For ANO-2 Cycle 2, a single value is used over all operating space. Therefore, $F_{SPLIT1} = F_{SPLIT2}$.

The F_{SPLIT} value, [ ], represents the adjustment factor to ensure CETOP-D always calculates a lower DNBR than detailed TORC over all operating conditions (ASI, pressure, temperature, flow).

Question 492.15 (A-16)

How is the value of power uncertainty factor of [ ] obtained for DNBR calculation?

Answer

The power uncertainty factor of [ ] results from the comparison of 6400 cases of CETOP-D and CETOP2 as shown in Figure 3. It represents the penalty applied to core power in CPC to ensure that DNBR results from CETOP-2 have a 95/95 probability/confidence level of being conservative relative to CETOP-D. A similar factor was determined for CPCTH, the corresponding CPC algorithm for ANO-2 Cycle 1, in CENPD-170-P Supplement 1-P to ensure that DNBR results from CPCTH have a 95/95 probability/confidence level of being conservative relative to BULL and COSMO.

Question 492.16 (A-17)

What is the value of the addressable DNBR uncertainty factor, BERR1, used in the calculation of heat flux at full power?

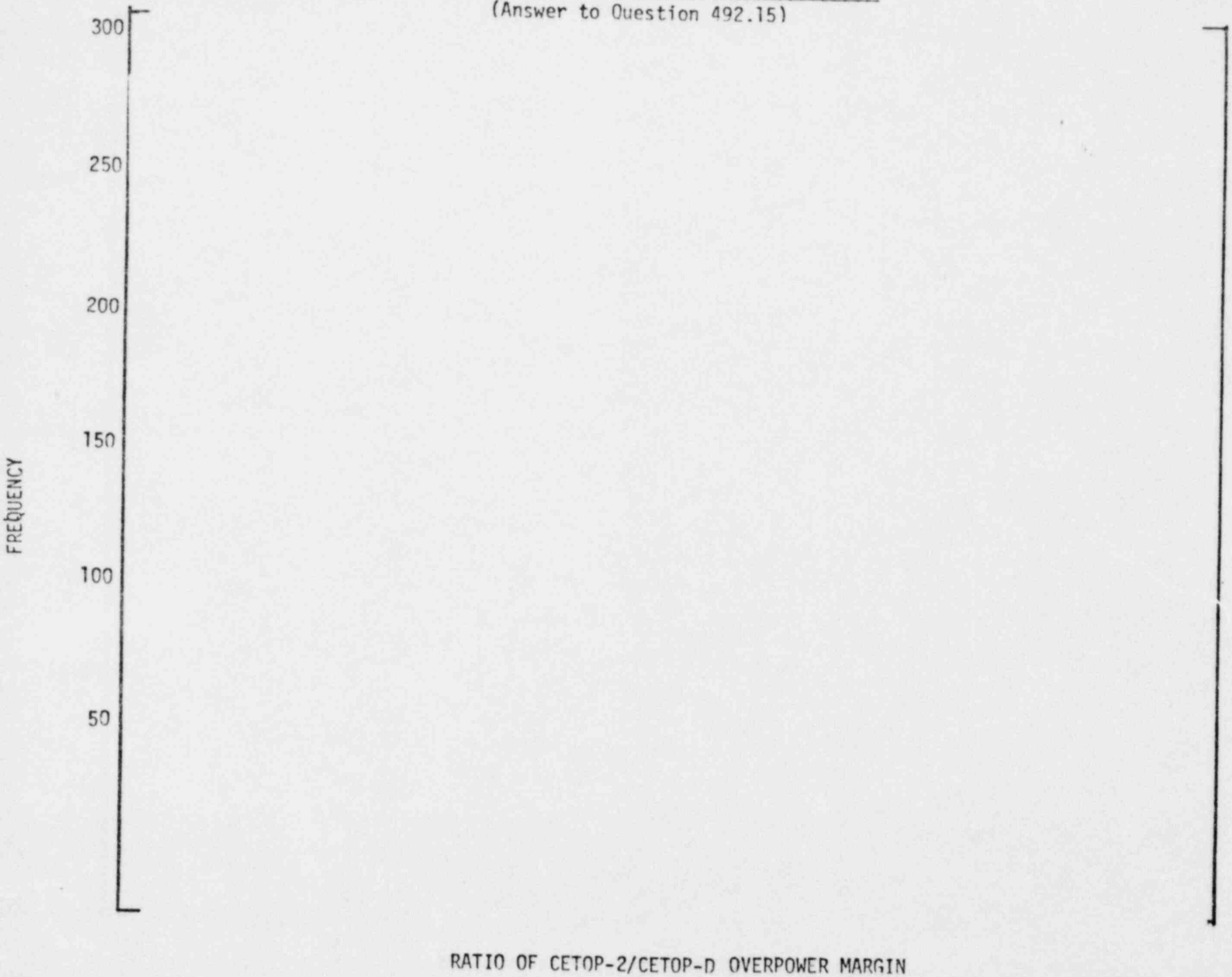
Answer

BERR1, the addressable DNBR uncertainty factor, is calculated at the conclusion of the CPC software modification effort. It can be provided along with the Phase II test report requested in Question 492.24.

FIGURE 3

CETOP-2 VS. CETOP-D ERROR DISTRIBUTION

(Answer to Question 492.15)



BERR1 was calculated in Cycle 1 by a combination of statistical and deterministic methods. As discussed in CENPD-170 Supplement 1-P and CEN-35(A)-P (answer to question 222.129), CPC DNB and power distribution algorithm uncertainties were determined by stochastic simulation. Detector noise, CEA position measurement errors, and certain processing errors were included in the simulation. The resultant uncertainties were then combined statistically by the root sum square (RSS) method with other uncertainties such as radial peak measurement errors and engineering factors. Other uncertainties including pressure, temperature, and flow measurement uncertainties were treated deterministically by multiplication of individual components. A numerical example of such a calculation was provided to L. Beltracchi of NRC following the uncertainty analysis audit of June 14, 1977.

For Cycle 2, BERR1 is being calculated by applying the more realistic statistical method, stochastic simulation, to calculate and combine CPC DNB and power distribution uncertainties, CEA position measurement errors, detector noise, processing errors and pressure, temperature and flow measurement uncertainties. The simulation technique used is similar to that described in CENPD-170 Supplement 1-P.

Engineering factors have been accounted for by increasing the MDNBR limit as described in CEN-139(A)-P and discussed in response to Question 492.25.

Question 492.17 (A-18)

In the linear heat distribution calculation, the P_2, P_3, and P_4 are defined as the corresponding channel power relative to channel 2. Explain the algorithm in the equations on page B-9.

Answer

P_2, P_3 and P_4 are only used in the form of ratios. Therefore, they can be normalized to any common value. The power in channel 2 is chosen for convenience.

Question 492.18 (A-19)

In the transverse momentum equation, which crossflow resistance correlation is used in CETOP-2? Is the crossflow resistance the same between core region - hot assembly gap and buffer channel - hot channel gap?

Answer

The crossflow resistance correlation used in calculation of the core region - hot assembly crossflow is the same as that used in TORC (Option 2, Section 3.4 of CENPD-161-P).

The crossflow resistance appropriate for the buffer channel - hot channel gap is small. For the range of interest, the actual value chosen has a negligible effect on the DNBR, as shown in CENPD-161-P. Therefore, for simplicity, this term is set to zero in CETOP-2.

Question 492.19 (A-20)

How is the value of turbulent interchange constant obtained? Provide a sensitivity study of turbulent interchange on DNBR.

Answer

The turbulent interchange constant (inverse Peclet number, .0035) was derived from cold water dye mixing tests. It was verified for 14X14 and 16X 16 assemblies from test data obtained at Columbia University (see CENPD-162-P-A.) A sensitivity study of turbulent interchange on DNBR is given in Appendix F of CENPD-162-P-A. Both CETOP-D and TORC use the same constant as is evident by comparing Table 4.1 of CENPD-161-P and Section 2.7 of the CETOP -D description provided in response to questions on CEN-139(A)-P.

Question 492.20 (A-21)

On page B-13, lines 3 and 6, "Section 2-11" and "2-12" should be "Section 2-12" and "2-13" respectively.

Answer

Correct

Question 492.21 (A-22)

Justify the use of the Newton difference formula and Bessel's interpolation formula to convert [ ] -node axial power distributions to [ ] point power distributions.

Answer

The Newton difference - Bessel interpolation scheme is a second order technique. It provides a better representation of the true flux shape than can be obtained by linear interpolation - extrapolation. The Newton difference-Bessel interpolation scheme is the Newton's divided difference formula*, adapted for use in the on-line CETOP-2 algorithm to obtain the required [ ] point power distribution from the [ ] node power distribution obtained from the on-line POWER algorithm. A typical result of applying this technique is shown in Figure 4.

Question 492.22 (A-23)

Provide a comparison of the CPC transient calculation to Cycle 2 design safety analyses for the loss of flow transient, the comparison safety analyses should be based on (a) CETOP/CE-1 (b) TORC/CE-1, and (c) COSMO/W-3.

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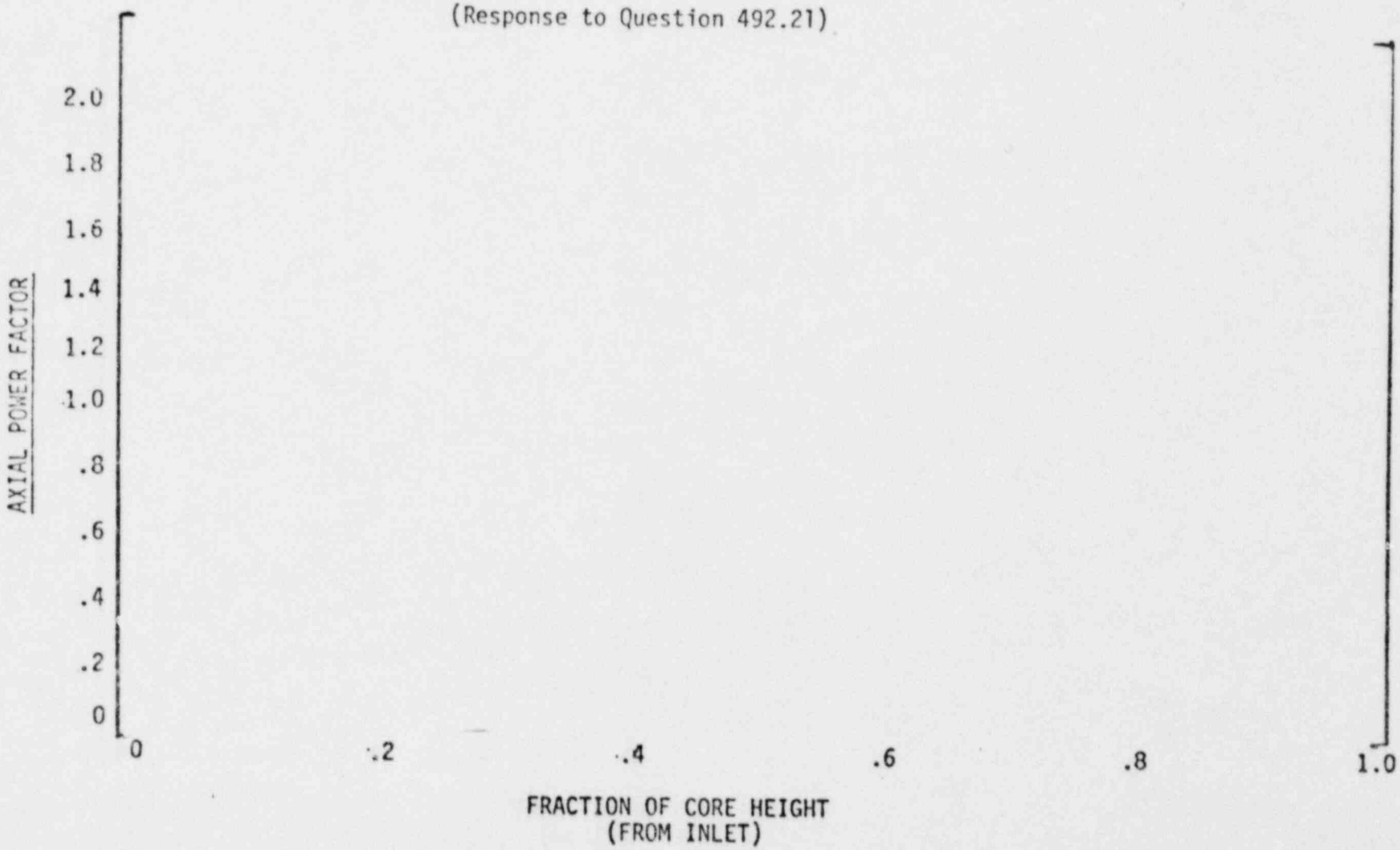
* B. Carnanahan, H. A. Luther, J. O. Wilkes, Applied Numerical Methods, Wiley and Songs, New York (1969).

FIGURE 4

AXIAL POWER DISTRIBUTION COMPARISON PLOTS

(Response to Question 492.21)



Answer

Comparisons between COSMO and TORC were presented in CENPD-161-P (Table 7.10). The CE-1 correlation is compared to W-3 in CENPD-162-P-A (Section 7.2). These comparisons apply to the DNBR's calculated during a loss of flow transient analysis.

The response to question 492.7 provides a comparison between TORC/CE-1 and CETOP/CE-1 over the whole spectrum of operating conditions. As discussed in the response to question 492.7 CETOP calculates DNBR lower than that calculated by TORC over the entire operating range. In addition, the response to question 492.27 provides comparisons of DNBR calculated by TORC and CETOP at the point of minimum DNBR during the loss of flow and CEA withdrawal transients.

A comparison of the CPC transient and design transient calculations for certain transients will be provided for ANO-2 Cycle 2. The design DNBR code will be CETOP and the NSSS simulation code will be CESEC. This comparison will be similar to the one performed for ANO-2 Cycle 1 and will consist of five transients. For Cycle 2 the transients will be:

1. Four pump loss of flow
2. One pump coastdown from four pumps running
3. Full length CEA drop
4. CEA bank withdrawal from 1% power
5. Pressurizer spray malfunction

The results that will be provided are:

1. Traces of the CESEC analysis DNBR (calculated by CETOP) vs. time
2. The required trip time determined from the CESEC analysis.
3. The latest expected CPC trip time as simulated by the CPC FORTRAN

Since the CPC FORTRAN Simulation code models CPC System calculational delays, the comparison cannot be completed until the CPC software disk is generated. The results will be provided with the CPC Phase II Test Report requested by Question 492.24.

Question 492.25 (A-26)

Provide a comparison table of values for CPC data base constants based on statistical combination of uncertainties (SCU) versus the values and uncertainty bands for the same constants without credit for SCU.

Answer

The use of Statistical Combination of Uncertainties (SCU) in treating system parameter* uncertainties as described in CEN-139(A)-P affects the minimum DNBR (MDNBR) limit in CPC and the various system parameter uncertainty factors in the ANO-2 Cycle 2 TORC and CETOP-D models and CPC DNBR algorithm (CETOP-2).

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* System parameters are those that describe the physical system and state parameters are those that describe the operational state of the reactor. State parameters and monitored during operation while system parameters are not.

As discussed in CEN-139(A)-P Section 2, the deterministic approach would involve applying system parameter uncertainties to the limiting subchannel in the CETOP-D model in the adverse direction. This is equivalent to assuming that all adverse deviations occur simultaneously in the limiting subchannel. On the other hand, the statistical method of CEN-139(A)-P being used for Cycle 2 accounts for system parameter uncertainties by incorporating them into a revised MDNBR limit for CPC and the safety analysis. A best estimate CETOP-D model is then used in the safety analysis and in the derivation of the CETOP-2 DNBR algorithm and constants. The use of this model and the revised MDNBR limit ensures to a 95/95 probability/confidence level that the limiting fuel pin will avoid DNB if the predicted MDNBR is not below the MDNBR limit.

As a result of the analysis presented in CEN-139(A)-P, the MDNBR limit for ANO-2 Cycle 2 was increased from 1.19 to 1.24. This corresponds to approximately [ ] overpower margin. It is estimated that the effect of the system parameter uncertainties treated by CEN-139(A)-P (Table 5-1), and the 2% rod bow penalty discussed in Section 6.2, if combined deterministically, would yield a penalty of approximately [ ] overpower margin. The net overpower margin gain is thus [ ].

Treatment of state parameter* uncertainties in CPC is independent of this statistical treatment of system parameter uncertainties and independent of CEN-139(A)-P. The treatment of state parameter uncertainties is discussed in response to Question 492.16. The only impact of CEN-139(A)-P on CPC data base constants is the change in the MDNBR limit to account for system parameter uncertainties and the corresponding removal of deterministic system parameter uncertainties.

Question 492.26

Explain how the application of SCU on the Cycle 2 differs from the uncertainty treatment in the Cycle 1 and its impact.

Answer

Statistical treatment of uncertainties has been employed in the ANO-2 Cycle 2 analysis in two independent areas.

Thermal-hydraulics system parameter uncertainties were treated statistically as described in CEN-139(A)-P. Reponse to question 492.25 discusses the impact of such statistical treatment.

The treatment of state parameter uncertainties and other factors that need to be applied to the DNBR calculation by CPC is discussed in response to question 492.16.

Question 492.27 (A-2)

Provide safety analyses based on an approved version of TORC/CE-1 for the loss of coolant flow and CEA withdrawal events.

Answer

Minimum DNBR (MDNBR) predictions with detailed TORC were compared to CETOP-D results for the loss of coolant flow and full power CEA withdrawal events. Comparisons were made at the operating conditions corresponding to the point of MDNBR in the transient. The detailed TORC results in Table 3 indicate that the MDNBR limit (1.24) is not violated and that there is conservatism in the CETOP-D results relative to detailed TORC results.

Table 3

MDNBR Comparisons Between Detailed TORC and CETOP-D

For Loss of Coolant Flow and CEA Withdrawal Events
(Response to Question 492.27)

	MDNBR		
Transient	Detailed TORC	CETOP-D	ΔMDNBR Conservatism in CETOP-D
Loss of Coolant Flow*	[ ]	1.240	[ ]
Full Power CEA Withdrawal*		1.240	

*Initial conditions are defined in the Reload Analysis Report Table 7.1.8-1 for the Loss of Coolant Flow transient and Table 7.1.6-5 for the CEA withdrawal transient.

Question 492.28 (A-27)

Compare the initial values of peak linear heat generation rate (kw/ft) used in Cycle 1 and Cycle 2 safety analyses for loss of flow and CEA withdrawal event. How are worst case initial conditions determined?

Answer

There has been no change in the peak linear heat rate (PLHR) LCO of 14.5 kw/ft or the fuel centerline to melt trip limit (21.0 kw/ft).

The loss of flow and CEA withdrawal are DNB limited events; therefore, PLHR does not enter into the analysis. The difference in DNB overpower margin associated with the change from Cycle 1 to Cycle 2 can be directly converted into a PLHR increase during steady state operation if the plant operates at its LCO's.

For example, during Cycle 1, the PLHR calculated by CECOR has ranged from 9 kw/ft to 11 kw/ft. The plant has been operating with a COLSS power operating limit (POL) near 110% power. Theoretically, the PLHR could incrase another 10% before reaching the DNBR LCO. One could consider a DNB overpower margin gain of X% for Cycle 2 as a potential allowed increase in PLHR by X%.

Answers to questions 492.25 and 492.29 discuss margin gains for Cycle 2 which can be substituted for the "X" in the above paragraph.

Question 492.29 (A-28)

Provide a quantitative assessment of DNBR margin (and equivalent power margin) gained as a result of proposed methodology changes for ANO-2 Cycle 2 versus ANO-2 Cycle 1. The assessment should include a tabulation of the individual components of the gain (e.g., use of SCU, CETOP/CE-1 vs. COSMO/W-3, etc.). Explain the impact of the margin gain on plant operating limitations.

Answer

The comparison of TORC to COSMO was presented in CENPD-161-P (Table 7.10). A comparison of the CE-1 critical heat flux correlation to W-3 was presented in CENPD-162-P-A (Section 7.2). For past reloads, we have seen that replacing COSMO/W-3 with TORC/CE-1 provides an overpower margin gain of [ ]

As shown in the response to Question 492.7 CETOP-D calculates DNBR lower than that calculated for TORC throughout the entire operating range. Therefore, use of CETOP results in no margin gain relative to TORC.

The margin relating to methodology changes in the treatment of system parameter uncertainties (CEN-139(A)-P) is discussed in the response to Question 492.25.

Any margin gain from TORC/CE-1 or SCU will balance increased radial peaks for Cycle 2 or allow wider ranges in axial shape , temperature, pressure or flow before reaching a COLSS limit or CPC trip. However, these ranges are limited by LCO's which prevent operation beyond the bounds of the safety analysis and any increase in margin to trip is reflected in that analysis.

None of these changes have affected the trip criteria for ANO-2. The fuel centerline melt limit remains 21.0 kw/ft. The DNBR limit for Cycle 2 will be the approved limit for the CE-1 correlation with adjustments for rod bow penalties and system parameter uncertainties as described in CEN-139(A)-P.

ANO-2 CYCLE 2

CPC SOFTWARE QUESTIONS

492.23 Provide the ranges of limits on addressable constants with evaluation of the impact of entry errors.

Response:

Attachment 1 contains a list of the addressable constants for ANO-2 cycles 1 and 2 software as well as the allowable range beyond which the computer will reject the entry of the constants. An assessment of the impact of entry errors as well as the frequency and purpose of use of each addressable constant follows:

1) F_{c1} and F_{c2} are used during startup testing following fuel loading or refueling in order to adjust the RCS flow rate measured by the CPC to the measured RCS flow rate using calorimetric methods and to adjust the CPC measured response to a flow coastdown following RCP trip, if required. F_{c1} is also used, if necessary, during monthly RCS flow rate surveillances to adjust CPC measured flow to be less than the calorimetric flow rate. (See ANO-2 Tech. Specs., Table 4.3-1, table notation items (7) and (8).) Entry of an incorrect value can be either conservative or non-conservative, and thus we must rely upon administrative controls to assure that the correct value is entered and maintained. The ANO-2 nominal values for F_{c1} and F_{c2} are ~1.10 and 0.0 respectively.

2) C_{INOP} is set to 0 if both CEAC's are operable, to 1 if CEAC #1 is inoperable, to 2 if CEAC #2 is inoperable and to 3 if both CEAC's are inoperable. Only integer values are acceptable. If an incorrect value is entered, the CPC channel may attempt to use data from an inoperable calculator the effect of which could be conservative or non-conservative. However, most errors would result in conservative action or would be of no consequence. Most CEAC computer failures will result in the CEAC fail bit being set which automatically marks that calculator as inoperable. If the C_{INOP} value were selected for the other calculator inadvertently, the CPC would automatically trip. If $C_{INOP} = 3$ is selected, a penalty factor is automatically applied to the DNBR and LPD values. Technical Specification 3.3.1.1, Table 3.3-1, Actions 5 and 6 detail the operating requirements corresponding to use of this addressable constant.

3) The five uncertainty terms B_{ERR0}, B_{ERR1}, B_{ERR2}, B_{ERR3} and B_{ERR4} are used to account for measurement uncertainties. The bias term ranges are 0 to 40, and the factor term ranges are 1.0 to 1.5; consequently, they can only increase the calculated LPD values reduce the calculated DNBR value. Only B_{ERR1} is routinely used during operation, and this use is for implementation of the rod bow penalty factors as required by ANO-2 Tech. Spec. 4.2.4.4.

4) The azimuthal tilt allowance, T_F is typically set at 1.03 for full power operation and is frequently changed during restarts

following reactor trips with transient core xenon conditions. Technical Specification 3.2.3 governs the required use of this addressable constant. Allowable values can only penalize the calculated DNBR and LPD values.

5) The power calibration constants K_{CAL} and C_{TP} are used frequently to meet the calibration requirements of ANO-2 Technical Specification Table 4.3-1 (see table notation item (2)). The use of these constants is controlled procedurally, and administrative controls must be relied upon to ensure the value is applied conservatively. Values less than one de-gain the calculated power level, but this is not necessarily non-conservative.

6) α_{R1} through α_{R7} are multipliers for the CPC planar radial peaking factor tables. The CPC values are determined to be conservative during startup testing after each fuel loading prior to exceeding 70% power, and the addressable multipliers are used should any measured peaking factor be determined to be larger than those used by the CPCS. ANO-2 Technical Specification 3.2.2 also requires monthly verification that the measured planar radials are smaller than those used by the CPCS. Past operating experience has not required use of these multipliers. Their use is controlled procedurally, and administrative controls must be relied upon to ensure conservative values are maintained. However, due to the infrequent use, errors are not likely.

7) α_{S2} through α_{S7} are the CEA shadowing factor multipliers for various CEA insertion patterns. These are verified during

startup testing following fuel loading by comparison with measured shadowing factors. The addressable multipliers are used only if necessary to ensure conservatism. Administrative controls must be relied upon to insure conservative application of the multipliers. However, the constants are not expected to change during the cycle, and thus entry errors are not likely due to infrequent use.

8) S_{ij} (i = 1, 3; j = 1, 3) are the shape annealing matrix addressable constants. ANO-2 Technical Specification Table 4.3-1, table notation item (5) requires determination of the proper shape annealing matrix elements and implementation of these addressable constants following each fuel loading. Other than as a result of this measurement, the matrix values are not expected to change during the cycle. Thus the likelihood of entry errors is small due to infrequent use. Inadvertent entry of an incorrect value would most probably cause the axial shape calculation in the CPC to fail and result in a channel trip. However, if one channel's values were entered incorrectly and the error did not result in a channel trip, the hourly cross channel comparison of ASI values by our operators would quickly point out the error.

9) The EOL flag is provided to cause selection of a different boundary point power formulation. If the axial flux shape changes from chopped cosine to saddle-shaped, the EOL flag may be changed administratively. During ANO-2 cycle 1, this change was not found to be necessary and may not be necessary

in later cycles. At any rate, only two allowable integer values are allowed (0 or 1) and due to infrequency of use, entry error is not deemed likely.

10) The penalty factor multipliers PF_{MLTD} and PF_{MLTL} are provided to allow direct penalization of the DNBR or LPD values calculated by the CPCS in the event of anomalous core conditions. These values would not normally be expected to change during the cycle, and thus entry error is unlikely due to infrequent use.

11) The DNBR and LPD pre-trip setpoints have been made addressable for ANO-2 cycle 2 for operator convenience. Since these pre-trips provide no safety function, entry error is not of concern.

12) C_{t1} is the temperature shadowing factor. The temperature shadowing effect is measured during initial startup testing, and the addressable constant value is not expected to change from cycle to cycle. Due to infrequent use, entry error is judged to be unlikely.

13) The boundary point power correlation constants B_{PPCC1} through B_{PPCC4} are measured during startup testing following each fuel loading. The addressable constant values are set at this time and are not expected to change during the cycle. Due to infrequent use, entry error is not considered likely.

As stated above, most addressable constants are not expected to change frequently. The only constants which are expected to change frequently during the cycle (following startup testing) are F_{c1}, F_{c2}, C_{INOP}, T_R, K_{CAL}, C_{tp}, the DNBR and LPD pre-trip setpoints (and possibly B_{ERR1} if the rod bow penalty factor treatment remains as in ANO-2 cycle 1). Operation of ANO-2 cycle 1 has indicated that the only potential problem related to entry error of the infrequently changed addressable constants is following software reload as a result of calculator failure or other maintenance. For this reason ANO-2 cycle 2 CPCS software has been modified to treat the infrequently changed constants differently. They will be referred to as Type II addressable constants and will be saved on an "addressable constant disk." These Type II constants which may change as a result of startup testing receive a high degree of quality control. The constants are calculated independently by two different engineers and are checked by Combustion Engineering representatives on site prior to entry. The data is also transmitted to C-E Windsor for review and independent verification. In addition, entry of each value is independently checked by two individuals (test engineers) and by the Shift Supervisor. Following startup testing, a new "addressable constant disk" will be generated for each CPC channel, and these disks will be used for software reload, when required. Then, for software reload, only six Type I addressable constants (F_{c1}, F_{c2}, C_{INOP}, T_R, K_{CAL} and C_{TP}) would require change from the default values on the software disk. It should be noted that the default values are:

F_{c1} = 1.0 (conservative relative to nominal ANO-2 value of $\simeq$ 1.10)

F_{c2} = 0.0 (same as nominal ANO-2 value)

C_{INOP} = 0 (value for no CEAC's inoperable)

T_R = 1.02 (which is approximately equal to the observed tilt at full power)

K_{CAL} = 1.0 (conservative relative to nominal ANO-2 value of ~0.98)

The DNBR and LPD pre-trip setpoints are not of concern since they do not perform any safety-related function.

Should changes to the Type II addressable constants be required during cycle operation, then new addressable constant disk(s) would be prepared and put into use. Periodic checks are mad of all addressable constants to ensure correct values are maintained.

492.24 Provide the CPC software test report.

Response

As agreed in our joint NRC/C-E/AP&L meeting held on March 26, 1981, in Bethesda, the CPC software test report will be made available to NRC in preliminary form upon completion of the Phase II software tests. In addition, AP&L and C-E will be prepared to support an audit of the test results at Windsor by NRC at that time. Completion of Phase II CPC software testing is presently expected by May 15, 1981. Therefore, the audit should be scheduled for the week of May 18, 1981. The final CPC software test report will be submitted on the ANO-2 docket within approximately one week after the preliminary document is made available to NRC.

ATTACHMENT 1

TABLE 1

ANO-2 CYCLE 1

ADDRESSABLE CONSTANTS

SYMBOL	DEFINITION	RANGE
F_{c1} F_{c2}	Core coolant mass flow rate calibration constants	0.8 to 1.3 -0.3 to 0.3
C_{INOP}	"CEAC/RSPT Inoperable" flag	0, 1, 2 or 3
B_{ERRO}	Thermal power uncertainty bias used in DNBR calculation	0 to 40
T_R	Azimuthal tilt allowance	1.0 to 1.4
K_{CAL}	Neutron flux power calibration constant	0 to 2.0
C_{TP}	Thermal power calibration constant	0.7 to 1.3
B_{ERR1}	Power uncertainty factor used in DNBR calculation	1.0 to 1.5
B_{ERR2}	Neutron flux power uncertainty bias used in DNBR calculation	0 to 40.
B_{ERR3}	Power uncertainty factor used in local power density calculation	1.0 to 1.5
B_{ERR4}	Power uncertainty factor used in local power density calculation	0 to 40.
α_{R1}, α_{R2}, α_{R3}, α_{R4}	Multipliers for planar radial peaking factors	0.9 to 2.0
α_{S2}, α_{S3}, α_{S4}	Multipliers for CEA shadowing factors	0.8 to 2.0
S_{ij} (i = 1, 3; j = 1, 3)	Shape annealing correction matrix	-250 to 250
EOL	End of life flag	0 or 1
PF_{MLTD}	DNBR penalty factor multiplier	-2.0 to -1.0 and 0.5 to 3.0
PF_{MLTL}	LPD penalty factor multiplier	-2.0 to -1.0 and 0.5 to 3.0

ATTACHMENT 1

TABLE 2

ANO-2 CYCLE 2

ADDRESSABLE CONSTANTS

SYMBOL	DEFINITION	RANGE
F_{c1} F_{c2}	Core coolant mass flow rate calibration constants	0.8 to 1.3 -0.3 to 0.3
C_{INOP}	"CEAC/RSPT Inoperable" flag	0, 1, 2 or 3
B_{ERRO*}	Thermal power uncertainty bias used in DNBR calculation	0 to 40
T_R	Azimuthal tilt allowance	1.0 to 1.4
K_{CAL}	Neutron flux power calibration constant	0 to 2.0
C_{TP}	Thermal power calibration constant	0.7 to 1.3
B_{ERR1*}	Power uncertainty factor used in DNBR calculation	1.0 to 1.5
B_{ERR2*}	Neutron flux power uncertainty bias used in DNBR calculation	0 to 40.
B_{ERR3*}	Power uncertainty factor used in local power density calculation	1.0 to 1.5
B_{ERR4*}	Power uncertainty factor used in local power density calculation	0 to 40.
α_{R1}, α_{R2}, α_{R3}, α_{R4*} α_{R5}, α_{R6}, α_{R7}	Multipliers for planar radial peaking factors	0.9 to 2.0
α_{S2}, α_{S3}, α_{S4}, α_{S5*} α_{S6}, α_{S7}	Multipliers for CEA shadowing factors	0.8 to 2.0
S_{ij*} (i = 1, 3; j = 1, 3)	Shape annealing correction matrix	-250 to 250
EOL*	End of life flag	0 or 1
PF_{MLTD*}	DNBR penalty factor multiplier	-2.0 to -1.0 and 0.5 to 3.0

ATTACHMENT 1

(Page 2)

TABLE 2

ANO-2 CYCLE 2

ADDRESSABLE CONSTANTS

SYMBOL	DEFINITION	RANGE
PF_{MLTL}*	LPD penalty factor multiplier	-2.0 to -1.0 and 0.5 to 3.0
A_2	DNBR pre-trip alarm setpoint	1.25 to 5.0
LPD_{PTS}	LPD pre-trip alarm setpoint (Kw/Ft)	10 to 20
C_{t1}*	Slope of the temperature shadowing correction factor	0 to 0.05
B_{PPCC1}, B_{PPCC3}*	Boundary point power correlation coefficients	0 to 1.0
B_{PPCC2}, B_{PPCC4}*	Boundary point power correlation coefficients	-1.0 to 1.0

*Type II addressable constants. All others are Type I.

Re ponse to NRC Questions on ANO-2
Cycle 2 Set C

Question C-1

(Paragraph 5.2.) For the limiting dropped CEA show the actual Cycle 2 calculated values of the reactivity worth and radial peaking factor shown in Table 5-5.

Answer

Table 5-5 lists "limiting safety analysis values" for the full length CEA drop analysis as:

minimum worth = 0.10%$\Delta\rho$

maximum increase in radial peaking factor (RPF) = 17%

The calculated values for the limiting case before application of uncertainties were:

minimum worth = 0.13% $\Delta\rho$

maximum increase in RPF = 14.2%

The values used in the safety analysis were chosen to include uncertainties and to bound future cycles.

Question C-2

(Paragraph 5.2.2.1) Regarding the use of the ROCS coarse mesh neutronics code give some typical examples of how and where it was used and the results obtained.

Answer

ROCS has been used in a manner consistent with current C-E reload methods approved by NRC for Calvert Cliffs Units I and II and St. Lucie Unit I. As was done for these plants, the following parameters were calculated for ANO-2 Cycle 2 with the ROCS computer code:

--Fuel Temperature Coefficients
--Moderator Temperature Coefficients
--Inverse Boron Worths
--Critical Boron Concentrations
--CEA drop distortion factors and reactivity worths
--Reactivity Scram Worths and Allowances
--Reactivity worth of regulating CEA banks
--Changes in 3-D core power distributions that result from inlet temperature maldistributions.

None of these parameters require detailed knowledge of pin peaking factors and in most cases are calculated more accurately by ROCS because of its ability to

Answer (cont'd)

to account for 3-D effects.

Data presented in Table 5-1, 5-2, 5-3 and 5-5 of the Reload Analysis Report were calculated using ROCS (except for delayed neutron fraction and neutron generation time in Table 5-1).

Question C-3

(Paragraph 5.3.3.2) DIT cross sections reportedly "substantially improved" the ROCS calculational result agreement with measurement on reactivity, power distribution, rod worths and reactivity coefficients. Provide some examples of the improvements mentioned in the cited paragraph.

Answer

C-E report TIS-6368 (attached) contains reactivity and power distribution comparisons from DIT-based and CEPAK-based models.

Question C-4

(Paragraph 10.3) It is not intuitively obvious that the annular pellets will have lower local peaking factors or that they will not impact neighboring rods. Provide explicit physics calculations to prove the assertions of this paragraph.

Answer

Figure 1 provides a comparison of PDQ calculations with and without annular pellet fuel rods in the configuration of the DOE high burnup demonstration assembly. It can be seen from this figure that fuel rods containing annular pellets are at least 3.8% lower in peaking than standard rods in the same locations. As Figure 1 also shows, the impact on neighboring rods is negligible, particularly in the context that these demonstration bundles are at low power levels in Cycle 2.

Question C-5

(Paragraph 10.3) Provide typical values of the impact on power peaking caused by the presence of the non-fuel region of the segmented fuel rods.

Answer

The maximum impact on power peaking caused by the presence of the non-fuel region of the segmented fuel rods is no greater than 8%. This impact is greatest in the region of the longer segment near the top of the core

Answer (cont'd)

(see Figure 10-1 of Reload Analysis Report) where axial peaks are lower.

Fuel rods affected by these non-fuel regions would have had power peaks at least 10% below the peak in the demonstration assemblies if the non-fuel regions were not present. Furthermore, the one-pin peak of the demonstration assemblies is at least 12% below the peak in the core throughout Cycle 2. Therefore, there is at least 14% margin between the fuel rods affected by the segmented rods and the power peak in the core.

Question C-6

Fuel misloading analysis has not been presented.

(a) Will such analysis be included in Section 7 which is to be submitted at a later date?

(b) When such analysis is submitted include analysis for position and orientation misloading.

(c) Has ANO-2 developed procedures to avoid misloading and misorientation?

Answer

The procedures developed for ANO-2 to avoid misloading and misorientation are described in Section 15.1.15 of the FSAR. These procedures include a redundant verification of proper fuel location and orientation.

A fuel misloading event analysis has not been presented for ANO-2 Cycle 2 for the following reasons:

1. Until December 1980, a fuel misloading event analysis was neither provided nor requested on any reload docket. A request for fuel misloading analysis was not made on the ANO-2 docket.

2. Quality control programs during fabrication and core loading and CEA symmetry checks and power distribution measurements at startup of ANO-2 Cycle 2 will be as extensive as they were for the first cycle.

3. Quality control and surveillance programs during fabrication and core loading make the likelihood of any misloading extremely remote.

4. If a misloading were to occur, CEA symmetry checks and power distribution measurements at startup would detect any misloading which would result in a significant margin degradation relative to the limiting anticipated operational occurrences (AOO). This was discussed in the ANO-2 FSAR and is equally true for Cycle 2. The most severe undetectable misloading which can occur in a first cycle is the interchange of a shimmed and an unshimmed assembly with similar initial k_∞. Such assemblies would operate at similar power densities at BOC and therefore such a misloading would be difficult to detect at BOC. Although margin degradation would be insignificant at BOC, the power mismatch would increase with burnup as the shims deplete (such mismatches would most likely eventually be detected by power distribu-

Answer (cont'd)

tion measurements). Since Batch D fuel does not contain shims, the magnitude of undetectable misloadings will be smaller than for the reference Cycle 1 analysis.

A fuel misloading event analysis was recently requested for Calvert Cliffs II Cycle 4 and will be presented in June 1981. This analysis will show that any misloading that affects power peaking enough to approach limiting AOO margin degradation will be detected at startup.

FIGURE 1
IMPACT OF ANNULAR PELLET FUEL RODS
ON RADIAL PEAKING FACTORS
(RESPONSE TO QUESTION C-4)