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February 2, 1990
BVY 90-011

United States Nuclear Regulatory Commission
Document Control Desk
Washington, DC 20555

Attention: Mr. Robert C. Jones, Chief
Reactor Systems Branch
Division of Systems Technology
Office of Nuclear Reactor Regulation

References: a. License No. DPR-28 (Docket No. 50-271)
b. Letter, USNRC to VYNPC, NVY 89-253, dated December 26, 1989.

Subject: Response to Request for Additional Information Regarding the Topical Report YAEC-1683 on MICBURN-3 / CASMO-3 / TABLES-3 / SIMULATE-3 Benchmarking

Dear Sir:

Reference (b) stated that the Reactor Systems Branch had reviewed the subject topical report and concluded that additional information was required for NRC to complete its review. As part of Reference (b), NRC provided an enclosure with a total of fifteen (15) questions relative to the subject report, and requested that Vermont Yankee submit responses to these questions within 30 days of receipt of Reference (b) to enable the NRC staff to complete its review. Reference (b) was received by Vermont Yankee on January 9, 1990.

Enclosed please find our responses to your questions. We trust that this information will assist you in your efforts to complete your review of the subject topical report; however, if you have any further questions or require additional information, please contact this office.

Very truly yours,

VERMONT YANKEE NUCLEAR POWER CORPORATION

Leonard A. Tremblay, Jr.

Leonard A. Tremblay, Jr.
Senior Licensing Engineer

Enclosure

cc: USNRC Region I Administrator
USNRC Resident Inspector - VYNPS
USNRC Project Manager - VYNPS

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RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION CONCERNING YAEC-1683, MICBURN-3/CASMO-3/TABLES-3/SIMULATE-3 BENCHMARKING OF VERMONT YANKEE CYCLES 9 THROUGH 13

QUESTIONS AND ANSWERS

1) Q. ***How will the reduced K_{eff} uncertainty impact the YAEC Licensing Analyses?***

A. On Table 5.7 of YAEC-1683, the hot eigenvalue standard deviation is reduced from $\pm$.00281 with SIMULATE-2 to $\pm$.00098 with SIMULATE-3. Most of this improvement with SIMULATE-3 is caused by a reduction in eigenvalue drift with exposure. As Figure 1.1 illustrates, both SIMULATE-2 and SIMULATE-3 track along well defined paths. It is the consistent behavior of the hot model's eigenvalue path which provides confidence in the predictions made during the licensing (e.g., end of cycle exposure, critical rod patterns for initiating transients, etc.). Since both models have well defined pathways, the hot portion of the licensing will not be affected by this reduction in hot K_{eff} uncertainty.

The reduction in cold K_{eff} uncertainty with SIMULATE-3 will also not affect the conservatism of the licensing analysis. YAEC does not intend to change the statistical level of confidence or the Technical Specification limit for cold shutdown margin as a result of the reduction in cold K_{eff} uncertainty.

2) Q. ***Describe the procedure used to adjust the CASMO-3G pellet densities when the calculated and measured assembly weights for a given fuel type disagree.***

A. A zero depletion step CASMO-3G case is run, for the majority lattice of the fuel bundle, using the nominal pellet stack density as an initial guess. The output from this zero depletion case provides the lattice cell area (cm^2) and heavy metal density (gmU/cm^3). Multiplying these values by the active fuel length (cm) produces an overall HM loading for the assembly (gmU). The latter is compared to the batch average of the as-loaded weights. The ratio of weights (as-loaded to CASMO-3G) provides an adjustment factor to correct the next CASMO-3G input density.

In general, one iteration is sufficient. For the fuel benchmarked in YAEC-1683, this procedure resulted in a 0.2-0.3% increase in stack density to achieve the batch averaged as-loaded weights.

3) Q. ***Will the Vermont Yankee SIMULATE-3 model be applied to fuel types that are not included in the Cycle 9-13 data base and how does the YAEC-1683 benchmarking justify this application? What are these new fuel types?***

A. Yes, the SIMULATE-3 (and CASMO-3G) model benchmarked in YAEC-1683 will be applied to fuel types not included in the Vermont Yankee (VY) Cycles 9-13 data base. Justification is based upon the concept that: This benchmark, along with others performed by YAEC and the code vendor, are consistent over a wide range of fuel parameters; therefore, small extrapolations beyond these ranges should exhibit similar behavior when modelled.

It is not possible, at this time, to define the future fuel types that VY might employ. However, the fuel vendors generally introduce design changes in evolutionary steps, which are usually tested by means of lead test assemblies (LTAs). This provides a long lead time in which to test SIMULATE-3 against vendor results for the LTAs. This should allow YAEC sufficient time to respond to any licensing or operational implications in an orderly manner.

4) Q. ***How do the CASMO-3G and SIMULATE-3 lattice parameters compare in the SIMULATE-3 "Audit" calculation?***

A. The "Audit" calculation of SIMULATE-3 shows that the CASMO-3G cross-sections, etc., are accurately transmitted by TABLES-3. For QA purposes, YAEC has found that the best overall figures of merit are the SIMULATE-3 generated values of K_∞ and M^2 listed in Audit. Typically, the absolute differences observed between CASMO-3G and SIMULATE-3 are less than .02% for K_∞, and less than .07% for M^2.

5) Q. ***Since some "leeway" exists in the specification of the thermal-hydraulic parameters, how were these parameters selected and how sensitive are the calculations to this selection?***

A. The "leeway" referred to on page 24 of YAEC-1683 consists of the following choices:

a.) Whether to use plant process computer generated subcooling as an input, or to use the internal SIMULATE-3 heat balance.

b.) Whether to turn on the spacer correction in SIMULATE-3, or leave it off.

For the benchmark, the plant process computer values of subcooling were used, because they were readily available. A subsequent sensitivity study, using the heat balance, gave virtually identical results to those shown in YAEC-1683.

With regard to the spacer correction, Cycles 9-13 were initially depleted without the spacer correction. Turning on the spacer correction resulted in minor changes: The spacer correction brought the hot eigenvalue closer to 1.0 and slightly improved the comparisons to plant instrument (TIP) readings as illustrated in Figures 4.10-4.12 of YAEC-1683.

6) Q. ***Describe the thermal-hydraulic adjustment made to account for the spacers. Why wasn't this effect accounted for by an adjustment of the local nuclear parameters?***

A. The EPRI-Void model, used in SIMULATE-3, does not account for the highly localized pressure drop and voiding effects in the immediate vicinity of the spacers. The spacer correction is an adjustment which accounts for the local accumulation of steam above the fuel spacers by increasing the local void fraction. The local void adjustment decreases to zero a small distance downstream of the spacer. Since the local accumulation of voids above the spacer is a physical thermal-hydraulic phenomenon it would not be appropriate to model its effect with adjustments to the nuclear parameters.

7) **Q.** ***How was the reactor period converted to reactivity in the cold-critical measurements?***

A. The reactivity correction ($-\rho$) for reactor period (T) was calculated using the in-hour equation. For large periods, the in-hour equation reduces to:

$$\rho = \sum_{1}^{6} \frac{\beta_i}{+\lambda_i T}$$

The six group β_i and λ_i point kinetics parameters are generated during the licensing of each cycle. The values of β_i change slightly from cycle to cycle, and change with exposure within a given cycle. The use of cycle and exposure specific values for β_i causes some variation in the period corrections used in the benchmark. These are plotted versus stable reactor period in Figure 7.1.

8) **Q.** ***What input does FIBWR provide?***

A. FIBWR is an approved licensing code which provides SIMULATE-3 with the split between active channel flow (moderator in contact with heated fuel rods) and bypass flow (moderator outside the channel plus flow up the water tubes). The split between the two is generated at several different values of total core flow. The bypass flow is input to SIMULATE-3 as a table versus total core flow.

9) **Q.** ***What axial and radial distribution of channel-bow was assumed in the Vermont Yankee calculations? What was the basis for this distribution and did it depend on fuel burnup?***

A. This is described in the answer to Question 14.

10) **Q.** ***Shouldn't the TIP uncertainty be $1/\sqrt{2}$ rather than 1/2 of the rms difference between symmetric TIPs?***

A. Yes it should be $1/\sqrt{2}$. The description of total TIP uncertainty provided on page 44 of YAEC-1683 is in error. However, the values for total TIP uncertainty shown in Table 5.6 of YAEC-1683 are calculated properly.

11) **Q.** ***How were the non-equilibrium state-points which were excluded from the calculation/measurement comparisons identified? Were other Cycle 9-13 state-points excluded from the benchmark comparisons and, if so, why were they excluded? Why aren't Cycle 11 and 12 EOFPL cold-critical comparisons included?***

A. As part of standard core follow guidelines, YAEC receives TIP data several days to a week following control rod maneuvers at the plant. This data is taken at, or near, xenon equilibrium conditions. The decision regarding the xenon equilibrium status of these transmitted TIP sets is made by Vermont Yankee (VY), based upon the steady behavior of power and flow versus time. All data provided to YAEC by VY, as part of standard core follow, was used in the benchmark. YAEC did not exercise any discretion in eliminating data from the benchmark.

Regarding the cold criticals: Cold criticals were not performed near EOFPL for Cycles 11 and 12 because VY did not scram near EOFPL in these cycles. End of cycle (EOC) cold criticals have not been performed at VY since Cycle 10.

12) Q. ***How did the calculation/measurement difference for the adjacent-rod critical compare with the typical differences obtained for the in-sequence critical measurements?***

A. The adjacent-rod critical (local critical) is the first critical shown on Table 5.4 of YAEC-1683. The local critical eigenvalue is .99258. This compares to an average for all cold criticals of .99680±.00168. Thus, the local critical falls outside the range of the standard deviation.

As a solitary data point, the deviation of the local critical from the average does not indicate a weakness in the methods, per se. As proof that the overall BWR methods are working, refer to the SIMULATE-3 topical YAEC-1659. The benchmark of Quad Cities, shown in Table 4.2 of YAEC-1659, contained 10 local criticals and 8 in-sequence criticals. The local criticals averaged .9983±.0005. The in-sequence criticals averaged .9967±.0026. These statistically overlap, demonstrating that SIMULATE-3 local critical results are consistent with in-sequence critical results.

13) Q. ***The proposed SIMULATE-3 model has essentially no factors for adjusting the model calculations in order to improve agreement with cycle specific measurements. If the calculation/measurement differences for a future cycle increase above the values given in YAEC-1683, how will this increased uncertainty be accommodated? Will the model be adjusted or will the uncertainty margin in the calculations be increased? How will this change be documented?***

A. If the calculation/measurement differences for a future cycle increase above the values given in YAEC-1683, the increased uncertainty would be statistically factored into the data base of those important parameters that affect licensing. The model would not be adjusted under these circumstances. Changes in the uncertainty margins, and how they are implemented to preserve conservatism in licensing, would be documented in the licensing process.

If, for any unforseen reason, changes to approved methods would be required, these would be reported to the USNRC.

14) Q. ***Provide a detailed description of the technique used to incorporate the results of the CASMO-3G calculations for the bowed-channel bundles in the CASMO-3G/SIMULATE-3 model. In addition to the deflection of the channel walls, are the fuel pins in the lattice also assumed to be displaced? How are the effects of channel-bowing on fuel rod power peaking accounted for?***

A. A conscious decision was made, when building the model, to keep it as simple as possible, while including the majority of known physical effects. With regard to channel bowing these physical effects are:

a.) Axially, the channel provides structural rigidity to the fuel. The spacers are in virtual contact with the channel and move with it.

b.) New channels have some bow which averages approximately 30 mils. The manufacturer pre-orients the bow away from the wide-wide corner to preclude any control rod interference.

c.) The fast flux gradient in D-lattices creates a positive feedback in differential Zr growth that causes bowing away from the blade to increase with exposure.

d.) The bowing in exposed channels has an axial shape that seems to follow the axial power distribution history.

Effect (a) is implemented in the model by having the entire lattice, pins and all, deflected in CASMO-3G by the amount of bow. This is achieved in CASMO-3G by simply adding to the dimensions of the wide water gap, while subtracting an equal amount from the dimensions of the narrow gap. Since the pins keep the same geometry relative to the channel walls, they have effectively moved with the channel-bow.

Changing the width of the water gaps affects the magnitude of local peaking as a function of burnup. The local peaking factors that CASMO-3G produces for the deflected lattice are input, via TABLES-3, directly into SIMULATE-3. Therefore, the effects of channel-bowing on fuel rod power peaking are accounted for.

Effect (b) is implemented by modelling the bow in CASMO-3G starting at zero exposure.

Effect (c) is partially implemented by using an amount of channel bow which is greater than the as-manufactured average bow (approximately 30 mils). As stated in Appendix C of YAEC-1683, a value of 40 mils was arbitrarily selected by the investigators to approximate the core average channel bow. Thus, some amount of increase due to burnup is included in the model. However, further change in bow during the cycle is not modelled. The amount of bow is kept fixed for the lifetime of the lattice.

Effect (d) is not included: A detailed axial shape was omitted to keep the model simple. The middle lattices of each fuel type are modelled in CASMO-3G with the same deflection for the 0%, 40% and 70% void depletion cases and branches. Figure 14.1 shows what the effective axial representation of the bowing is in the model. For axially zoned fuel, the top and bottom fuel zones are assumed to have no deflection. All middle fuel zones are run in the CASMO-3G model as if they were uniformly deflected by the full amount of the assumed bow.

To summarize the answer to Question 9, based on the details provided above: The axial and radial distribution of channel-bow in the model is uniform. The amount of bow (uniform deflection) modelled is arbitrarily set at 40 mils. This amount of bow exceeds the as-manufactured amount; therefore, some of the increase in channel-bow with burnup is included in the model. However, the assumed amount of deflection in the model remains fixed during the cycle.

15) Q. In view of the wide range in coolant temperatures during the cold critical tests (Table 5.4), is a temperature correction applied to the cold critical eigenvalues of Figure 5.2?

A. The temperature of each cold critical statepoint is explicitly input into the given SIMULATE-3 case. This is sufficient to allow SIMULATE-3 to interpolate between cross-section sets at 68°F and 300°F. No correction is made to the final SIMULATE-3 answer except for the reactivity adjustment for reactor period (see answer to Question7).

Figure 1.1

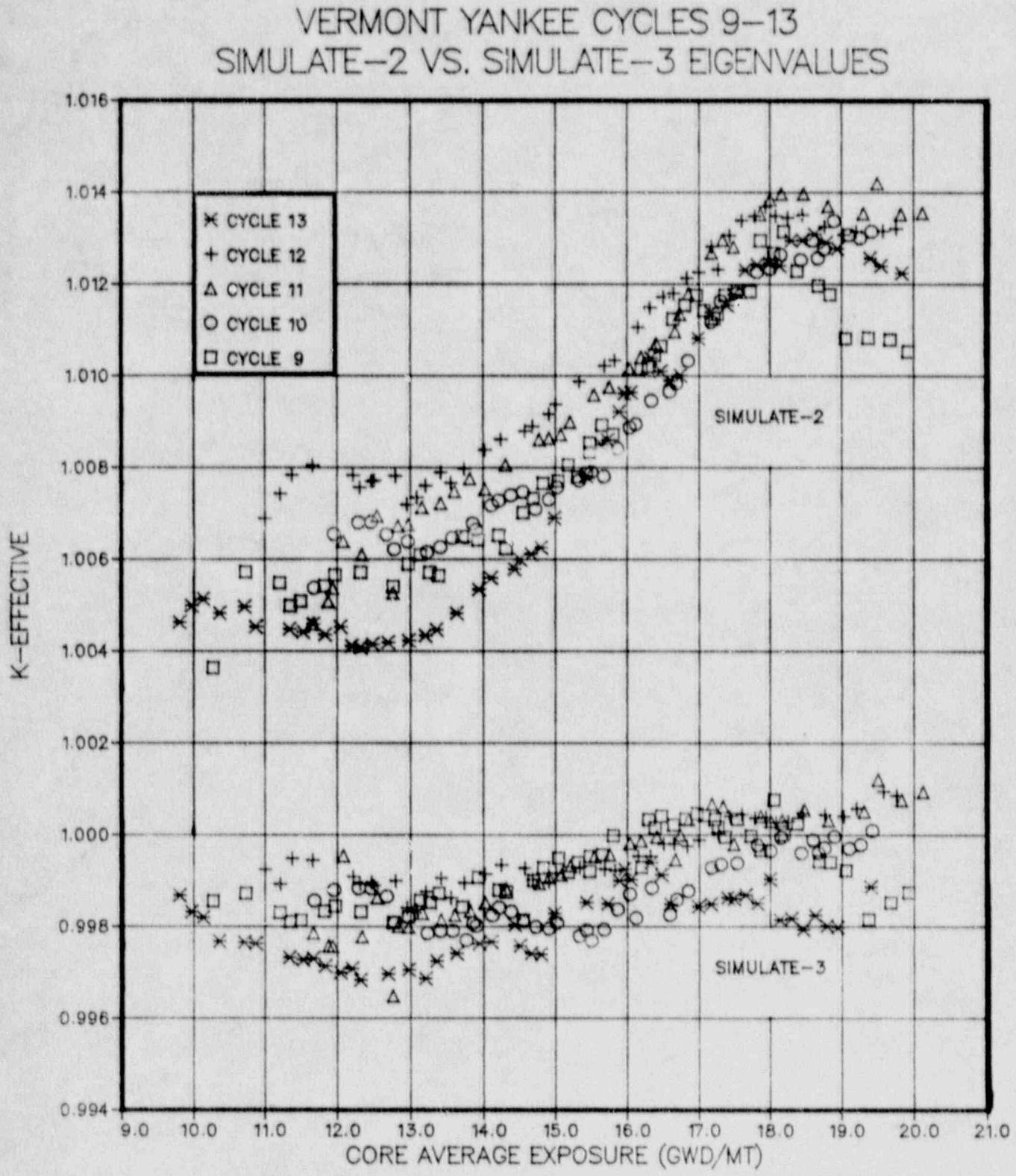

VERMONT YANKEE CYCLES 9–13
SIMULATE–2 VS. SIMULATE–3 EIGENVALUES
CYCLE 13
CYCLE 12
CYCLE 11
CYCLE 10
CYCLE 9
SIMULATE–2
SIMULATE–3
K–EFFECTIVE
CORE AVERAGE EXPOSURE (GWD/MT)
1.016
1.014
1.012
1.010
1.008
1.006
1.004
1.002
1.000
0.998
0.996
0.994
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0

Figure 7.1

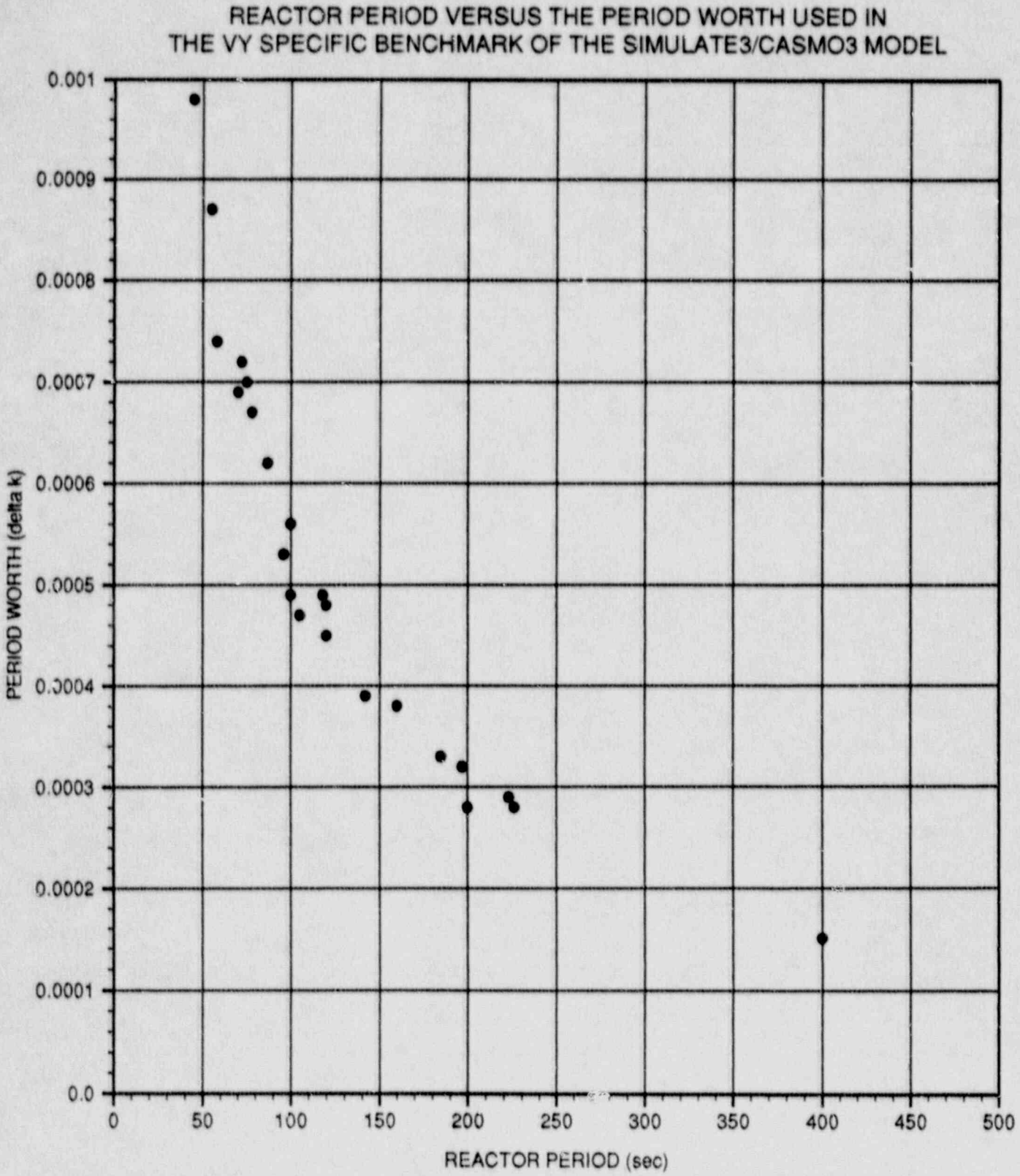
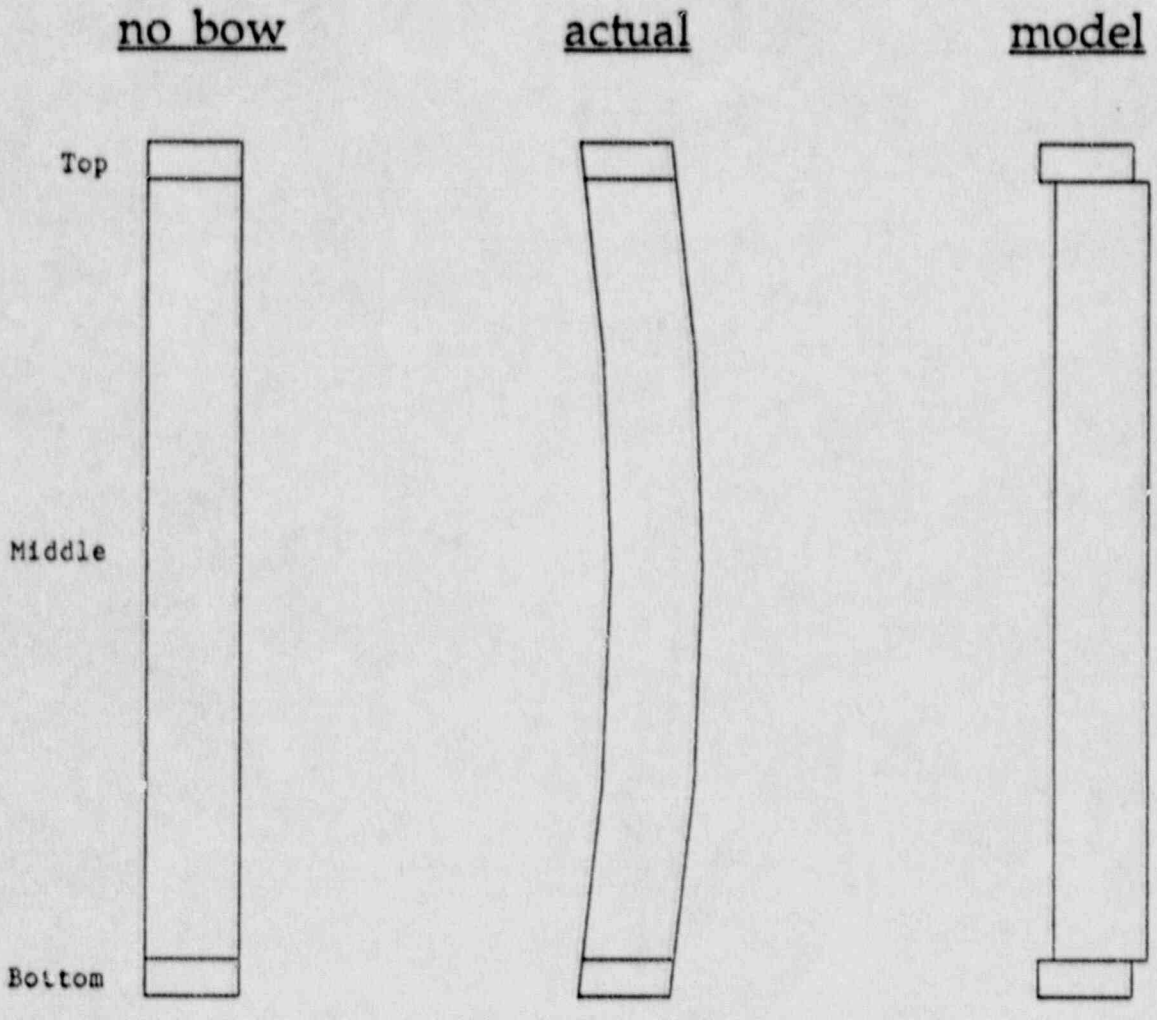

REACTOR PERIOD VERSUS THE PERIOD WORTH USED IN
THE VY SPECIFIC BENCHMARK OF THE SIMULATE3/CASMO3 MODEL
PERIOD WORTH (delta k)
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0
0
50
100
150
200
250
300
350
400
450
500
REACTOR PERIOD (sec)

Figure 14.1

UNIFORM DEFLECTION OF THE MIDDLE ZONE AWAY FROM THE WIDE-WIDE CORNER



Simple Model For Channel Powing