ENCLOSURE 5 TO LAP-83-576

NF-1583.03-1

Nonproprietary Version

# METHODS OF PRESTO-B

# A THREE-DIMENSIONAL, BWR CORE SIMULATION CODE

# AMENDMENT 1

# (NONPROPRIETARY VERSION)

RESPONSE TO NRC QUESTIONS

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(8688WRM/cfr)

# INTRODUCTION

This amendment to Topical Report NF-1583.03, "Methods of PRESTO-B: A Three-Dimensional, BWR Core Simulation Code," is provided in response to requests for additional information as conveyed by Enclosure 2 of the letter to Mr. E. E. Utley, CP&L, from Domenic B. Vassallo, NRC Division of Licensing, dated November 1, 1983.

QUESTION 1 (NF-1583.03)

(Cover Page)

Typo: LWR should be BWR

RESPONSE

We regret any inconvenience caused by this typographical error. The title of the Topical Report NF-1583.03 is: "METHODS OF PRESTO-B, A THREE-DIMENSIONAL, BWR CORE SIMULATION CODE."



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QUESTION 2 (NF-1583.03)

(Page 4-2)

How is continuity in a cross-section at the boundary between burnup intervals in POLGEN assured?

RESPONSE

Continuity in a cross-section at the boundary between burnup intervals is assured in POLGEN by overlapping the burnup ranges by one or more points in exposure. Five burnup points are used to determine the fourth order fit of cross sections as a function of burnup in each subdivision. This method assures continuous cross sections and piece wise continuous cross-section derivatives as a function of exposure.



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QUESTION 3 (NF-1583.03)

(Section 4.2.2)

In the transient xenon model in PRESTO-B, the effective microscopic absorption cross-section for xenon, $\sigma_x$, is modified by a coefficient $\kappa_x$ that is a function of void fraction and xenon density. How are the effects of burnup on $\sigma_x$ accounted for?

RESPONSE

Typical variation of $\sigma_x$ and $\kappa_x$ in the range from 0 to 15,000 MWD/TU of burnup are:

2,3

$\sigma_x$:
$\kappa_x$:

This dependence is neglected in the parametric representations of $\sigma_x$ and $\kappa_x$ by Eqs. 4.11 and 4.12 of Section 4.2.2.

Note that the microscopic Xenon cross-section is used only to account for deviations in local Xenon concentrations from the equilibrium value contained implicitly in the base cross-sections (Section 4.1).

The burnup dependence of the microscopic Xe cross-section is accounted for in the calculation of the base cross-section in RECORD.



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QUESTION 4 (NF-1583.03)

(Section 4.2.2)

Provide a typical functional form of the spectral coefficient, $\eta_f$ used in the xenon model.

RESPONSE

The spectral coefficient $\eta_f$ used in Eq. 4.10 of the Xenon model is evaluated from RECORD calculations at 40% void and zero burnup for each nuclear fuel type. $\eta_f$ decreases slightly with burnup and also exhibits some void dependence. The total variance is within within the range of 0-70% void, 0-15,000 MWD/T of burnup. The void and burnup dependence in $\eta_f$ is neglected in PRESTO since the resulting correction factor ($1 - \eta_f \cdot X$) is always close to unity (typically for equilibrium Xenon concentration, X). | 2, 3 | 2, 3

The burnup dependence of the microscopic Xe cross-section is accounted for in the calculation of the base cross-sections in RECORD.



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QUESTION 5 (NF-1583.03)

(Section 4.4)

Under what conditions are the coefficients $b_2$ and $b_3$ determined. For example, are they determined for the full power equilibrium value of samarium concentration?

RESPONSE

The basic cross-section data input in the form of POLGEN polynomials contain the effects of equilibrium Sm-149. The coefficients $b_2$ and $b_3$ are used to account for deviations from the equilibrium concentrations and are determined as:

$b_2 =$

$b_3 =$

2.3

Separate sets of coefficients are determined for use in zero-power and at-power cases; the first is generated from CZP - 0% void data and the latter from HFP - 40% void data.

QUESTION 6 (NF-1583.03)

(Eq. 4.2.1)

Provide more detail on the manner in which the correction term, $h_4$, is obtained.

RESPONSE

The correction term $h_4$ of Eq. 4.21 is defined as:

$h_4$ = 2, 3

where $\Delta\Sigma a_2^{(1)}$ is the control rod absorption term obtained from single bundle RECORD calculations, using Eq. 4.20, and $\Delta\Sigma a_2^{(4)}$ is the corresponding quantity derived from 4-bundle 5-group RECORD-MD2 calculations with one rodded and three unrodded bundles.

$\Delta\Sigma a_2^{(4)}$ is obtained by performing the 5 group to 2 group collapsing based on the bundle wise average group fluxes of the 4-bundle model. Typical values based on data for BWR 8x8 fuel are:

Hot, operating condition $h_4$ =
Cold condition $h_4$ = 2, 3

QUESTION 7 (NF-1583.03)

(Section 4.5)

How will the introduction of the GE hybrid control rod affect the calculation of control rod reactivity and burnup?

RESPONSE

The present design of the GE hybrid control rod includes a few full-length hafnium rods in the high flux region. This design still, however, uses a large number of boron bearing rods for overall reactivity control. At the present time, the RECORL cross-section library is being modified to analyze partial or complete hafnium control rods. Once these modifications are complete, a study will be conducted which evaluates the neutronic performance of the hybrid rods compared to present designs. The results of this study will determine whether or not the present PRESTO-B control rod model should be modified to account for reactivity and burnup performance of the GE hybrid control rod.

QUESTION 8 (NF-1583.03)

(Eq. 4.2.1)

Provide the functional form of $f(\Sigma)$ and typical numbers showing the dependence of $f(\Sigma)$ on the 2-group constants, $\{\Sigma\}$.

RESPONSE

The function $f(\Sigma)$ of Eq. 4.21 is defined as:

$f(\Sigma) =$ 2,3

Typical numerical values are:

| Void fraction $\alpha$ | $f(\Sigma)$ |
|---|---|
| 0 | 2,3 |
| 0.4 | |
| 0.70 | |



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QUESTION 9 (NF-1583.03)

(Section 4.5.3)

Provide additional details of the model that describes control rod history effects on the two-group constants, including the explicit dependence of the group constants on the variables of interest.

RESPONSE

Control rod history effects are modeled by correction terms $\Delta\Sigma a_2$ and $\Delta\nu\Sigma f_2$ to the corresponding nodal thermal group cross-sections. These correction terms are updated in each burnup step as follows:

- Initial values for fresh fuel $\Delta\Sigma a_2 = 0$

  $\Delta\nu\Sigma f_2 = 0$

- Control rod adjacent to node during step i -> i + 1:

$\Delta\Sigma_{i+1}$ =

where

$\Delta E_i$ = nodal exposure increment

a and b are fuel type dependent coefficients (separate constants for $\Delta\Sigma a_2$ and $\Delta\nu\Sigma f_2$) evaluated as illustrated in Fig. 9.1.

2, 3

- No control rod adjacent to node during step i -> i + 1 :

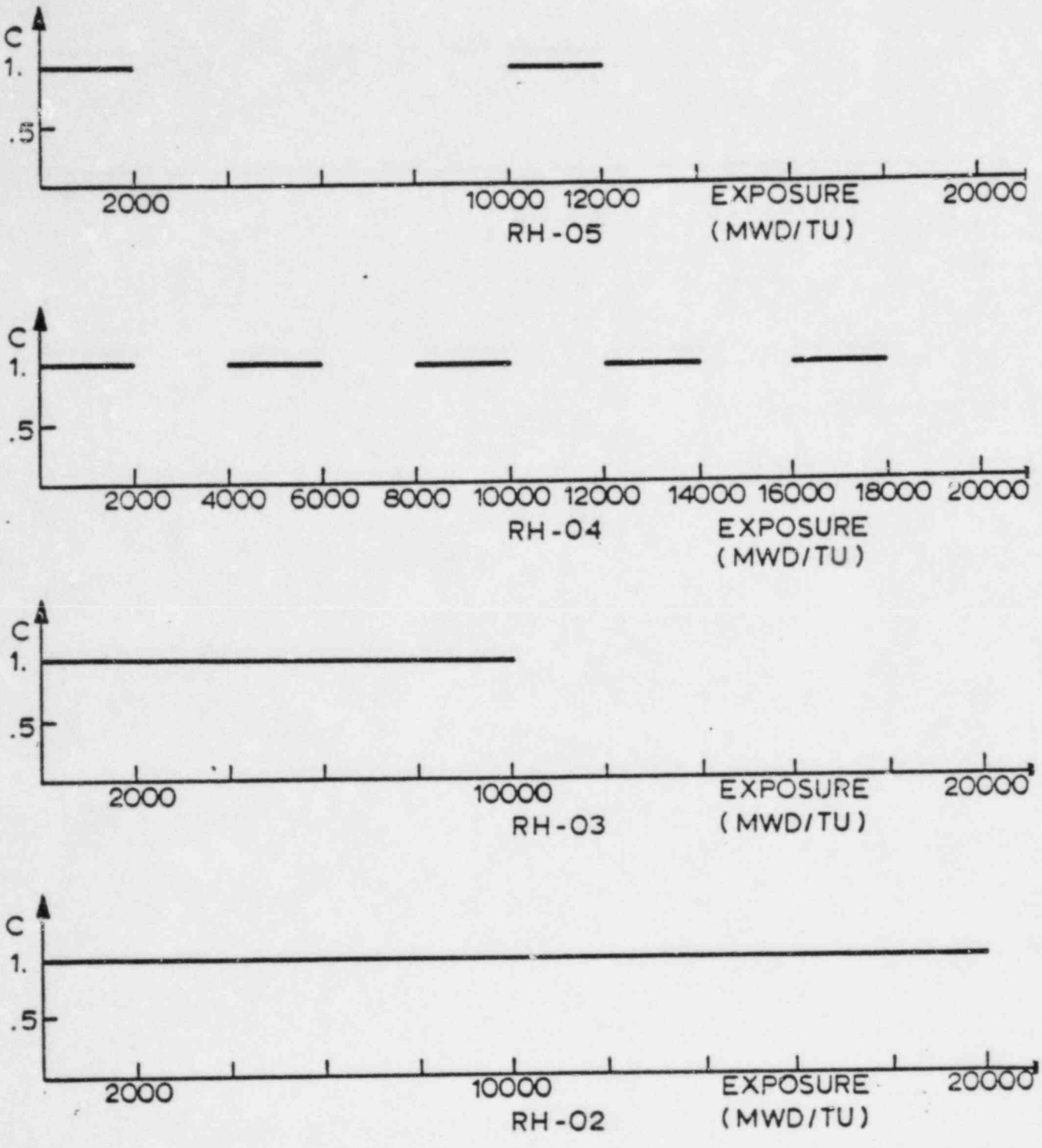
$\Delta\Sigma_{i+1}$ =

$\Delta\Sigma(1)$ and $\Delta\Sigma(3)$ are fuel type dependent constants evaluated from RECORD calculations with rodded depletion from zero to 10,000 MWD/T (Point 1) and unrodded depletion from 10,000 to 20,000 MWD/T (Point (1) to Point (3), Fig. 9.1).

An evaluation of this model against explicit RECORD calculations for four different control rod histories is shown in Figs. 9.2, 9.3 and 9.4.

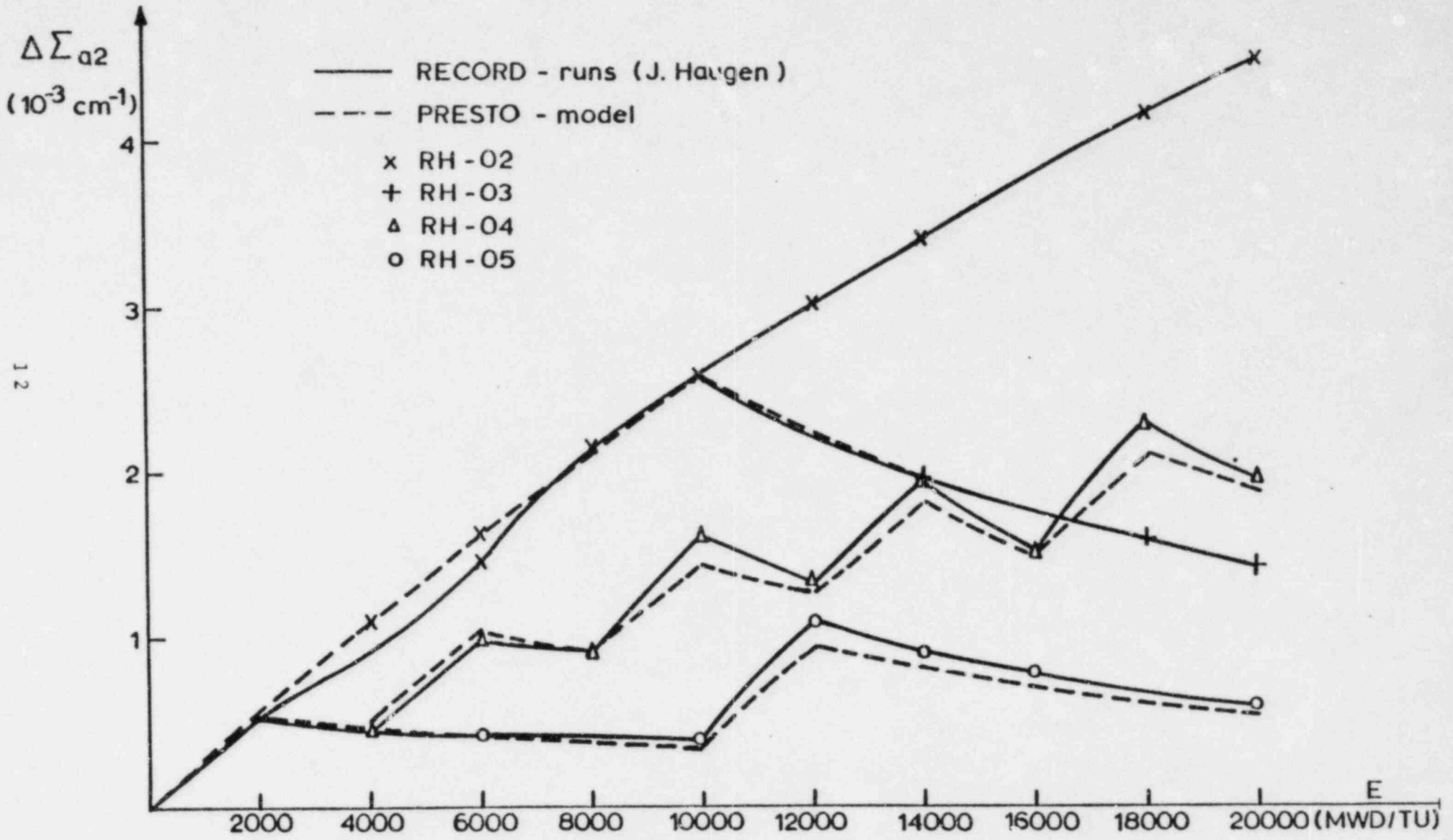
FIGURE 9.1

FIGURE 9.2



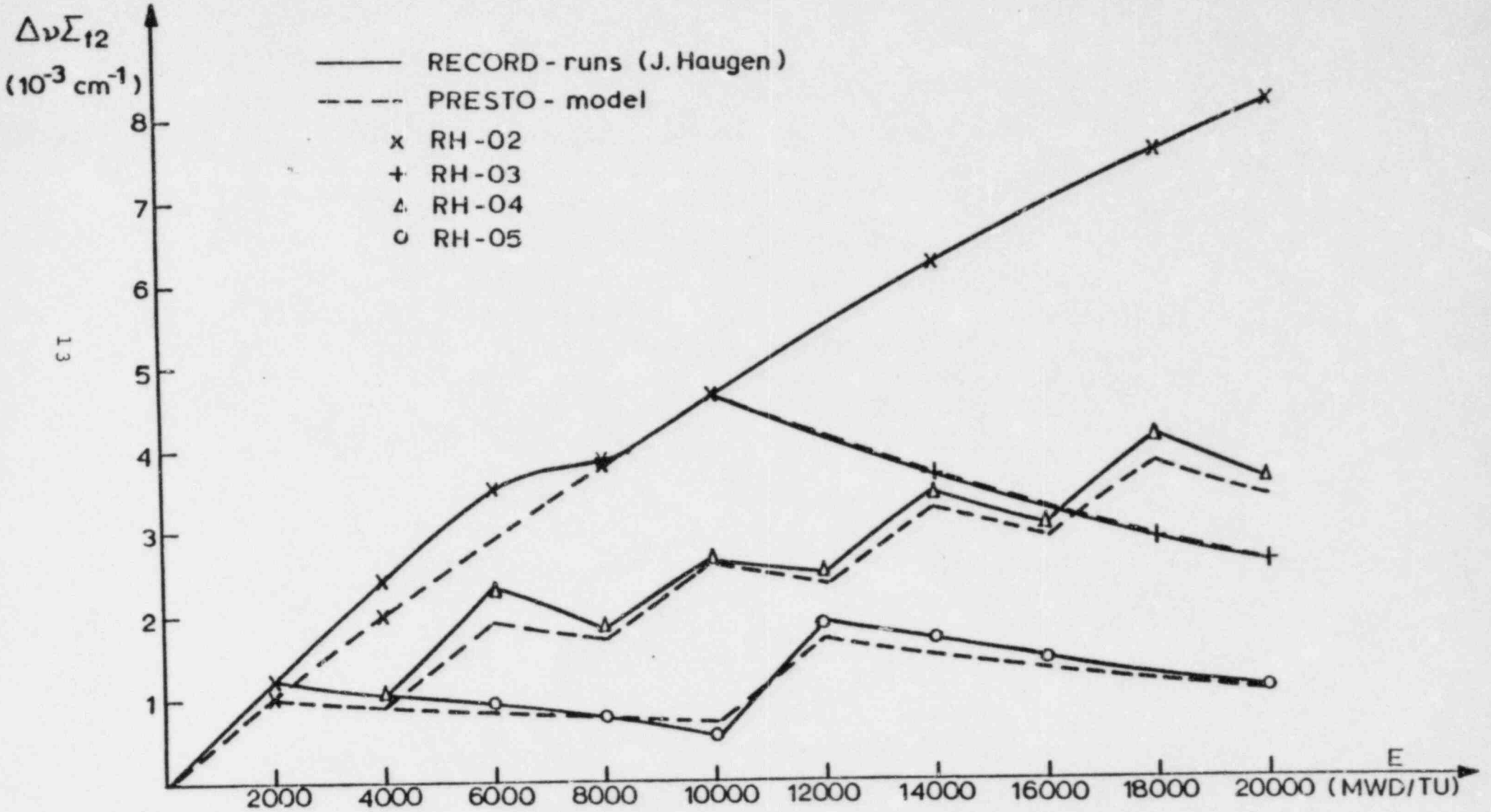

Control rod histories used for comparison of PRESTO-B's control history correction with explicit RECORD results.

FIGURE 9.3




$\Delta\Sigma_{a2}$ for the rod histories shown in fig. 1.

FIGURE 9.4




$\Delta\nu\Sigma_{12}$ for the rod histories shown in fig. 1.

QUESTION 10 (NF-1583.03)

(Section 6.1)

The thermal energy content of the reactor vessel walls is neglected in the reactor vessel energy balance equation. Since the pressure vessel has a thermal time constant of between one and ten minutes, the neglect of the reactor vessel thermal energy leads to inaccuracies of quasistatic changes in reactor conditions over comparable durations of time. Specifically, PRESTO-B may not be used for heatup/cooldown calculations.

RESPONSE

The PRESTO-B heat balance equations have been developed by assuming that the reactor vessel control volume is in equilibrium. Variations from the equilibrium assumption can be introduced by modifying the radiation power term input, Qrad, provided that the time constant is sufficiently long to permit the feedwater system to come to equilibrium. In practice, however, neglecting the vessel heat conduction is slightly conservative for cooldown transient. The heatup transients need to be addressed on a case-by-case basis.



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QUESTION 1? (NF-1583.03)

(Section 6.2.9)

Provide the bases for the correlation between the effective Doppler temperature and the power density used in PRESTO-B.

RESPONSE

The PRESTO-B doppler fuel temperature model applies a linear variation in fuel temperature as a function of local power. In addition, PRESTO-B permits a quadratic variation in average fuel temperature as a function of exposure. This relation is shown in NF-1583.03 Section 6.2.9.

The exposure dependent average fuel temperatures are generated in the fuel performance code, by assuming constant operations at the lattice average linear heat generation rate, from zero to the lattice physics cut-off exposure. This permits the modeling of average fission gas release, and pellet and clad dynamics.

The best estimate doppler temperature is based on a form presented in Reference 1, this being;

$$T_D = \alpha T_A + (1 - \alpha) T_S$$

where $T_D$, $T_A$, and $T_S$ are the doppler temperature, fuel pellet average temperature and surface temperature respectively. The interpolation constant is set to $\alpha = 0.85$.

The PRESTO-B doppler fuel temperature input is balanced to account for the following effects;

1) Reported bias between the fuel performance code and measurements. When COMETHE-IIIJ is used, the bias reported in Reference 2 is appropriate,

2) the spatial distribution of resonance absorption within the fuel pellet,

3) the fuel temperature dependency on linear heat generation rate, and,

4) a need to conservatively estimate power feedback for licensing applications.

When COMETHE-IIIJ is employed as the fuel performance code, the effective doppler temperature at the lattice average linear heat generation rate is represented as;

$$T_{DOPPLER} = 0.85\ \overline{T}_{COMETHE} + 43.8°K$$

where $\overline{T}_{COMETHE}$ is the COMETHE radially averaged fuel temperature.



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Figure 11.1 compares the PRESTO-B and best estimate power to doppler fuel temperature relationship for a GE P8x8R lattice at 8 GWD/MTU. The power range of 1 to 15 KW/ft. spans conditions of normal operation and allows for 20% overpower on the peak core node, during a power transient. As can be seen, the linear power to temperature relation is sufficiently accurate to be used for steady state applications.

References:


1) S. L. Forkner, et.al., "Three-Dimensional LWR Core Simulation Methods," Tennessee Valley Authority, TVA-TR78-03, June 1, 1978.

2) EPRI, "Evaluation and Modification of COMETHE III-J," EPRI-NP-2911, March 1983.




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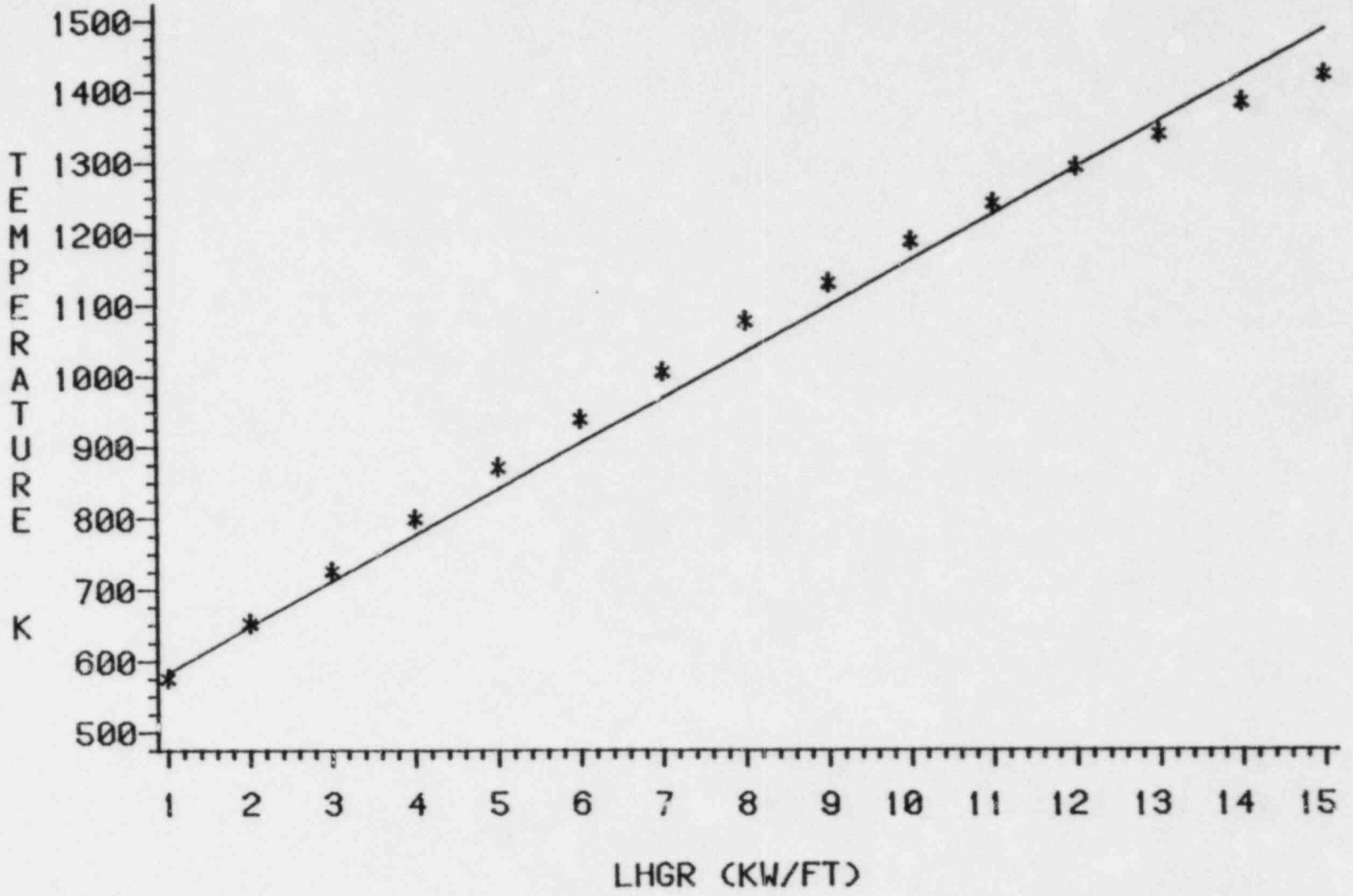
**FIGURE 11.1**
DOPPLER TEMPERATURE VS.
LINEAR HEAT GENERATION RATE (LHGR)
*=T BEST EST. ——— =T PRESTO-B



QUESTION 12 (NF-1583.03)

(Table 6.1)

Is the set of recommended values for thermal-hydraulic parameters valid for all steady state applications? Were all calculated void distributions presented in figures 11.9 through 11.37 obtained with the given set of recommended parameters?

RESPONSE

The set of thermal-hydraulic parameters of Table 6.1 are valid for steady state applications. (Ref. Table 11.3).

All calculated void distributions presented in Fig. 11.9 through 11.37 were obtained with the same set of Thermal Hydraulic Model Parameters as follows:

$A_F$ = 2400.
$G_1$ = 0.22
$G_2$ = 0.2
$B_1$ =
$B_2$ =
$v_1$ =
$v_2$ =
$v_0$ =
$\delta_D$ =
$R_0$ =
$R_1$ =
$\kappa$ =
$\delta_1$ =
$\delta_2$ =

2,3

The data for the velocity correction of the slip correlation ($B_1$, $B_2$, $v_1$ and $v_2$) differ slightly from the recommended set. Reanalysis of the FRIGG data, using the parameters of Table 6.1 gave the following result:

| Data Set | Average Deviation (%) | Std. Deviation (%) |
|---|---|---|
| Table 6.1 | -1.1 | ±2.2 |
| Original analysis, Figs. 11.9-11.37 | 0.6 | ±2.1 |
| Experimental Uncertainty | | ±2.0 |

The parameters of Table 6.1 give a slight underprediction of void at low flow for the FRIGG data but have been optimized against BWR low power, low flow conditions and are thus recommended for actual BWR analysis.

QUESTION 13 (NF-1583.03)

(Eq. 7.6)

How is the formula used to account for 3-D effects near the tip of a control rod arrived at? What are the typical errors in eigenvalue and peaking factor introduced through its use?

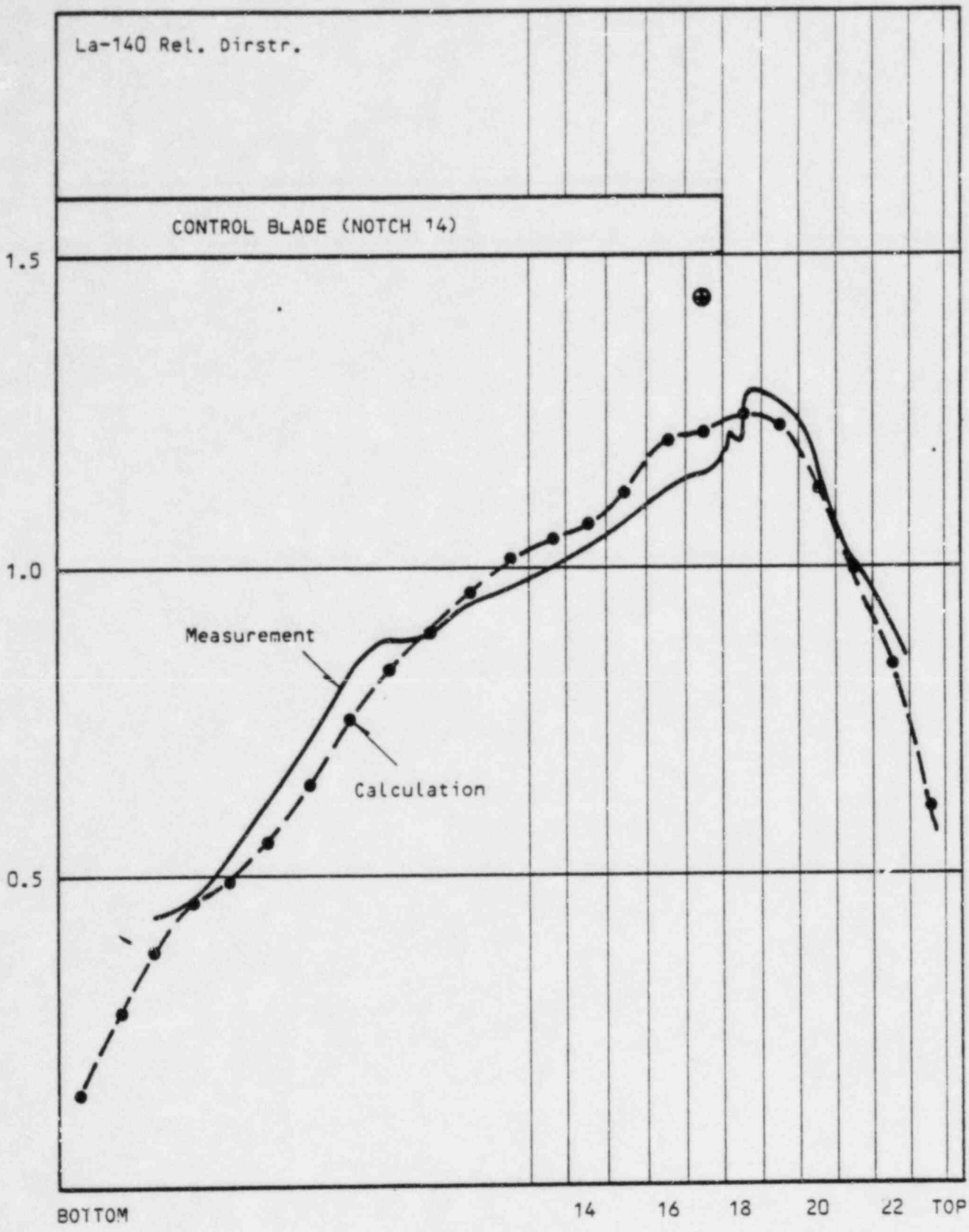
RESPONSE

Peaking factors obtained from 2-D RECORD calculations for the rodded conditions are generally higher than for the unrodded condition. In PRESTO, such peaking factors are used to calculate the maximum linear heat generation rate for assemblies adjacent to inserted control blades. Rodded condition peaking factors are used up to a point located one node below the end (tip) of the blade. A gradual, linear, transition from rodded to unrodded condition is assumed for the last (one node long) part of the blade. This is modeled through Eqs. 7.5 and 7.6.

This model has been evaluated by analysis of pin-wise gamma scan data (Hatch I) as illustrated in Figs. 13.1 and 13.2. Pins located in the N-N corner were chosen to represent typical peak locations for the rodded condition. The calculated curves were obtained by multiplying the nodal La-140 distributions with N-N corner pin peaking factors evaluated by Eq. 7.5. Calculated points obtained without the correction formula (Eq. 7.6) are also shown for comparison. These are seen to produce pronounced, unrealistic spikes on the calculated curves.

Thus, the formula used to account for 3-D effects near the tip of a control rod improves the peaking factor calculation. It has no effect on calculated eigenvalues since the nodal 2-group cross-section data are unaffected.

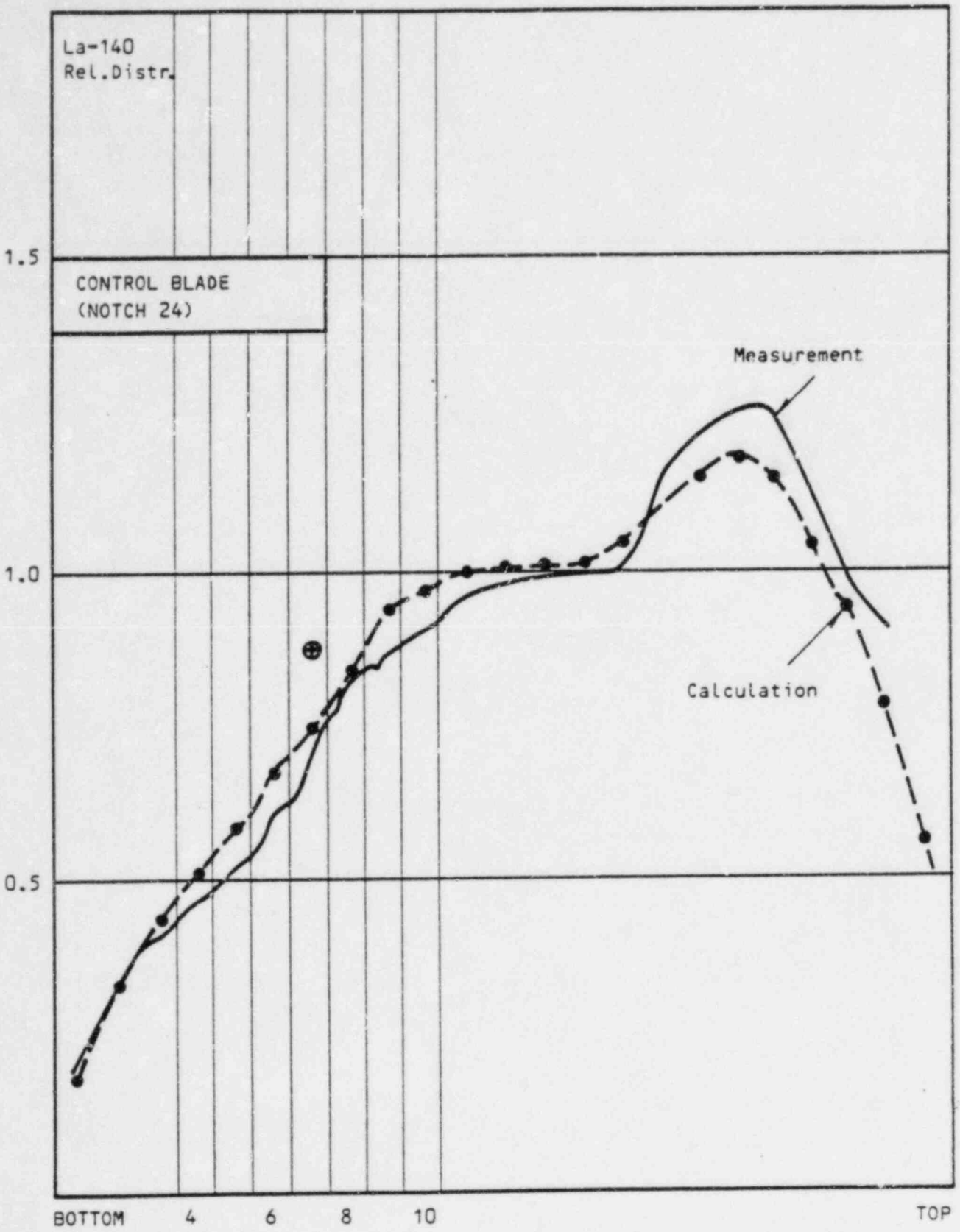
FIGURE 13.1




Comparison of measured and calculated axial distributions of single pin La-140, Hatch I, HX373.

⊕ Denotes calculation without PRESTO control rod tip correction formula.

FIGURE 13.2




Comparison of measured and calculated axial distribution of single pin La-140. Hatch I, HX393.

⊕ Denotes calculation without PRESTO control rod tip correction formula.

QUESTION 14 (NF-1583.03)

(Section 8.1)

The four fuel bundles surrounding a TIP string can be affected directly by the insertion of one, two, three or four control blades. Do the m-factors defined in (8.1) account for all these possible control rod configurations?

RESPONSE

The m-factors are generated in RECORD for completely rodded and completely unrodded configurations. Insertion of one, two, three or four control rods (completely rodded) is modeled by applying the rodded m-factors to the rodded bundles and the unrodded m-factors to the unrodded bundles. In practice, the configurations which are of most interest are unrodded, one rod or two diagonally adjacent rods. Comparisons to many 3-D TIP distributions have demonstrated that no additional configuration dependent adjustments are required.

QUESTION 15 (NF-1583.03)

It is stated that a detailed fuel performance code, such as COMETHE, will be used to provide average fuel temperature to PRESTO. The COMETHE code has not been approved for use in plant safety analysis. Will this code be submitted for NRC review?

RESPONSE

The use of COMETHE by CP&L is historical. At the time of initial development of CP&L BWR steady-state analysis capability, COMETHE was an EPRI sponsored code which provided a substantial improvement in predictive capability compared with other available codes. EPRI has since transferred their development efforts in this area to FCODE. Ongoing investigations will determine whether COMETHE, POSHO-THERMAL, FCODE or an alternate methodology is suitable for our safety analysis applications.

The PRESTO-B fuel temperature is used to provide power feedback to the cross-sections, and as such has no other use. The PRESTO-B fuel temperatures are not intended for the evaluation of stored energy or clad performance and, therefore, do not require review for these applications. The need to submit COMETHE for staff review should be viewed in the context of its limited usage by CP&L for PRESTO-B input.

CP&L would prefer not to submit COMETHE for NRC review. The subject of fuel performance will be addressed in future submittals concerning BWR system transient modeling.



(8688WRM/ccc)

ENCLOSURE 6 TO LAP-83-576