

CEN-345(B)-NP

RESPONSES TO NRC
QUESTIONS ON FATES3B

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COMBUSTION ENGINEERING, INC.

8610240084 861021
PDR ADOCK 05000317
P PDR

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QUESTION 1

Will the FATES3B code replace FATES3A code for all licensing applications? If not, please explain which codes will be used for which licensing application. Also, will the inputs described in CEN-193(B), Supplement 2-P (dated March 21, 1982) for FATES3 licensing applications remain the same for FATES3B licensing applications. The conservative input used in FATES3B for calculating LOCA initialization provides a conservative bias to this thermal calculation in addition to the inherent bias in the code. Please provide an estimate of the conservative bias in centerline temperature that is introduced in FATES3B by the conservative LOCA input. Also, please provide a representative licensing calculation each for LOCA initialization and end-of-life rod pressure as an example of these applications.

RESPONSE 1

It is intended that the FATES3B code replace FATES3A for all Baltimore Gas and Electric licensing applications. All licensing applications for FATES3B remain the same as given for FATES3 in CEN-193(B), Supplement 2-P (dated March 21, 1982).

The input data for the FATES3B licensing applications remain the same as that for FATES3 described in CEN-193(B), Supplement 2-P, except for normal cycle-to-cycle variations. The procedure for introducing conservatism into the stored energy for the LOCA analysis is described in detail in CEN-193(B), Supplement 2-P. This LOCA initialization licensing methodology is not expected to change when using FATES3B. The bias in centerline temperature that is introduced in FATES3B by the conservative LOCA input is essentially the same as that calculated for FATES3. This calculation of introduced conservatism is documented in CEN-220(B)-P (dated October 5, 1982). The introduced conservatism on volumetric average fuel temperature is still on the order of []

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The licensing calculation performed using FATES3B for Calvert Cliffs Unit 1 Cycle 9 LOCA initialization is also used for the maximum end-of-life operating pressure. A set of values for FATES3B mechanical design and thermal-hydraulic data are provided in Table 1-1. The power history data are presented in Figures 1-1 and 1-2. The [] for the Calvert Cliffs Unit 1 Cycle 9 analysis is plotted in Figure 1-1. Figure 1-2 is a plot of the [] as a function of rod position, for the Calvert Cliffs Unit 1 Cycle 9 analysis.

Predicted temperatures and rod pressure for the aforementioned Calvert Cliffs Unit 1 Cycle 9 analysis are provided in Figures 1-3 and 1-4. Figure 1-3 is a plot of the fuel centerline and fuel average temperatures as a function of rod average burnup. These temperatures are calculated based on the [] peak power level. Figure 1-4 is a plot of the rod internal pressure prediction as a function of rod average burnup.

Table 1-1
FATES3B Input Parameter Data

<u>Parameter</u>	<u>Value</u>
pellet diameter, in.	[
active fuel length, in.	
pellet length, in.	
fuel grain size, microns	
nominal fuel density, % TD	
tolerance on initial density, % TD	
densification, % TD	
pellet surface roughness, in.	
fuel enrichment, wt%	
clad outer diameter, in.	
clad inner diameter, in.	
clad length, in.	
end plenum void volume, in ³	
total fuel rod void volume, in ³	
air partial pressure, psi	
fill gas partial pressure, psi	
helium in fill gas, fraction	
nitrogen in fill gas, fraction	
clad surface roughness, in.	
heat transfer area per foot of rod per unit flow area, ft ⁻¹	
convective heat transfer coefficient, Btu/hr-ft ² -°F	
maximum gap conductance, Btu/hr-ft ² -°F	
minimum gap conductance, Btu/hr-ft ² -°F	
coolant pressure, psia	
coolant mass velocity, lbm/hr-ft ²	
coolant inlet enthalphy, Btu/lbm	
core average LHGR, kw/ft	
core average fast flux (> 1.0 MEV), /n/cm ² -sec	

Figure 1-1

CALVERT CLIFFS 1,CYCLE 9



ROD AVERAGE BURNUP,GWD/MTU

Figure 1-2

CALVERT CLIFFS 1,CYCLE 9
BOL POWER VS AXIAL HEIGHT

ROD POWER,KW/FT

FRACTIONAL AXIAL HEIGHT

Figure 1-3

CALVERT CLIFFS 1, CYCLE 9
FUEL TEMPERATURE VERSUS BURNUP

FUEL TEMPERATURE, DEG F
(Thousands)

ROD AVERAGE BURNUP, GWD/MTU

Figure 1-4

CALVERT CLIFFS 1, CYCLE 9
PRESSURE VERSUS BURNUP

ROD INTERNAL GAS PRESSURE, PSIA
(Thousands)

ROD AVERAGE BURNUP, GWD/MTU

QUESTION 2

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RESPONSE 2

FATES3B was developed to give improved predictions of fission gas release, with particular emphasis on improving the fission gas release predictions at high burnup. As part of the FATES3B development process, C-E compiled and reviewed PWR high burnup, high temperature fission gas release data available from the open literature as well as from C-E programs. The development of the FATES3B fission gas release model was based on the data utilized in CEN-161(B)-P, the RIS0 data discussed in CEN-193(B)-P, and the following high burnup, high temperature data sets:

1. Super-Ramp (Studsvik) Program,
2. DOE High Burnup Ramp Program,
3. Zorita Research Development Program, and
4. Westinghouse Research Program in BR-3.

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The five unpressurized BWR RISO rods were previously analyzed with FATES3 at the request of the NRC to provide additional verification of the FATES3 gas release model. This is documented in Reference 2-1. These rods were reanalyzed with FATES3B. The measured fission gas release values for Rods PA29-4 and M2-2C from Test 022 are well predicted by FATES3B. As was the case in Reference 2-1, the measured gas release values for Rods M20-1B, M2-2B, and T9-3B from Test 013 are considerably greater than the FATES3B predictions for these rods. The FATES3B temperature predictions for the Test 013 rods are lower than for the Test 022 rods, which is consistent with the differences in the reported irradiation histories of the two sets of rods. However, the post-irradiation metallographic examination of the fuel pellets do not indicate any significant difference in operating temperatures between rods of the two different test series, which is consistent with the observed gas release. The higher-than-expected fission gas release in the Test 013 series, based on reported test conditions, is unexplainable, and these three data points remain as outliers. It is C-E's position that although attempts to predict these rods are of interest, they carry no weight in assessing the quality of the fission gas release model.

The DOE High Burnup Ramp and Petten Ramp data should also be evaluated but must be used cautiously due to the well-known effect of the position of the test rig in the Petten Reactor on the test results. This effect is discussed in Reference 2-2. A core-distance parameter has been shown to affect fission gas release and PCI performance among PWR rods ramped at the Petten reactor. At Petten, ramp tests are performed in test capsules that reside outside the core. Rod powers are increased by moving the test capsule closer to the core. The required movement is relatively small (see Reference 2.2) and the rod is subjected to important power gradients across the rod. Various factors

influence the radial position relative to the core periphery that must be attained by a given rod to achieve a predesignated peak ramp power. A correlation has been determined, for example, showing that rods requiring the least distance from the core released significantly more fission gas and had less PCI resistance than sister rods reported to be at the same power level, but at a greater distance from the core. The core-distance effect is likely to be most pronounced for higher burnup fuel, which as a group, require the least distance from the core to attain higher ramp powers. This is an important consideration for the DOE High Burnup Ramp data. PWR fuel similar to that ramp tested at Petten was also ramp tested at the R2 reactor as part of the Over-Ramp and Super-Ramp programs. [

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Figure 2-1 of this response is a plot of the predicted versus measured gas release for the [] data points. The RISO Test 013 rods, DOE High Burnup Ramp rods, and Petten Ramp rods are identified with a separate symbol. The subset of reliable data created by removing the suspect RISO Test 013, DOE High Burnup Ramp rods, and the Petten Ramp rods from the set of rods [

] Figure 2-1 shows that predicted versus measured gas release for the reliable subset of rods are well predicted on a best-estimate basis, especially considering the limited number of reliable data points available in the high release regime. Figure 2-2 provides the entire FATES3B fission gas release data base with these suspect rods identified.

For the [], predicted-minus-measured gas release percent does not appear to be either burnup or temperature dependent. Figure 2-3 is a plot of the predicted-minus-measured gas release as a function of rod average burnup for the high measured gas release

rods. Likewise, Figure 2-4 is a plot of predicted-minus-measured gas release as a function of peak linear heat rate. Peak linear heat rate can reasonably be considered to correlate with the peak fuel temperatures. In each of these plots, the RISO Test 013, DOE High Burnup Ramp, and Petten Ramp rods are again identified with a separate symbol. Whether or not the RISO Test 013, DOE High Burnup Ramp, and Petten Ramp data points are included, the FATES3B predicted-minus-measured gas release percent appears to be quite independent of burnup or power level.

Considering (1) how well the high fission gas release is predicted when the questionable data is removed (see Figure 2-1), and (2) that the predicted-minus-measured gas release (error) is independent of burnup and power level (or temperature) [], it can be concluded that the FATES3B gas release model is adequate for predicting fission gas release. Because of only a slight bias [] the impact on licensing calculations is negligible.

REFERENCES for RESPONSE 2

2-1 Combustion Engineering, Inc., "Partial Response to NRC Questions on CEN-161(E), Improvements to Fuel Evaluation Model", CEN-193(B) Supplement 2-P, March 21, 1982 (Proprietary).

2-2 J. C. LaVake and M. Gaertner, "High Burnup PWR Ramp Test Program, Topical Report Background Ramp Test Results", DOE-ET/34030-4, CEN-402, December 1982.

Figure 2-1

FISSION GAS RELEASE
PREDICTED VS MEASURED FGR

PREDICTED FISSION GAS RELEASE, %

MEASURED FISSION GAS RELEASE, %

Figure 2-2

FISSION GAS RELEASE
PREDICTED FGR VS MEASURED FGR

PREDICTED GAS RELEASE, %

MEASURED GAS RELEASE, %

Figure 2-3

FISSION GAS RELEASE

PREDICTED—MEASURED VS BURNUP

PREDICTED—MEASURED FGR, %

ROD AVERAGE BURNUP, GWD/MTU

Figure 2-4

FISSION GAS RELEASE
PREDICTED—MEASURED VS PLHR

PREDICTED—MEASURED FGR, %

PEAK LINEAR HEAT RATE, KW/FT

QUESTION 3

Are the fission gas release and thermal expansion models the only differences between FATES3A and FATES3B codes.

RESPONSE 3

The only differences between FATES3A and FATES3B codes are the models related to fission gas release and the thermal expansion model as described in CEN-161(B)P, Supplement 1-P. Although C-E changed the grain growth model as described, grain growth is considered to be part of the fission gas release model. However, it should be noted that FATES3A is considered to be the FATES3 code (CEN-161(B)-P) with the NRC imposed restriction on the grain size used in the fission gas release calculations. The grain size restriction is not part of FATES3B. The descriptions in Supplement 1-P for FATES3B only include the FATES3B differences from the original FATES3 code described in CEN-161(B)-P.

QUESTION 4

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RESPONSE 4

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QUESTION 5

Are the thermocouple data points used for FATES3B comparisons in Table 3-13 and Figures 3-3 through 3-5 the same data as used for the FATES3 comparisons in CEN-220(B) (dated October 5, 1982). If data were added or deleted please explain why each data group was added or deleted. Also please provide a copy of CEN-220(B).

RESPONSE 5

The data groups (rods) used to examine the FATES3B bias and uncertainty in predicting fuel temperatures are the same as those used for the FATES3 comparisons in CEN-220(B). Specifically, measured versus predicted temperatures were presented for the following test rods: [

] However, the FATES3B modeling of the [] rods was improved, resulting in [] data points for these [] test rods. The number of data points for the same [] rods presented in CEN-220(B) was []