CEN-205(B)-NP

RESPONSE TO NRC QUESTIONS

ON FATES3 AND THE

CALVERT CLIFFS 1 CYCLE 6 RELOAD

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Question 1

Has the Combustion Engineering ECCS evaluation model (STRIKIN) been modified to account for revisions in the FATES3 code in areas such as gap conductance?

Response 1

The Combustion Engineering ECCS evaluation model did not require modification to account for revisions in the FATES3 code. The ECCS model and computer codes, including the hot rod heatup code STRIKIN-II, remain unchanged from those approved by NRC for compliance with 10CFR50, Appendix K. STRIKIN-II utilizes the FATES3 burnup dependent characterization of fuel rod conditions (fuel density, pin pressure, fission gas content, plus cold clad and fuel dimensions) as input. STRIKIN-II then initializes itself based on this FATES3 input and the ECCS analysis assumptions of peak kw/ft and limiting axial power distribution.

Question 2

Do the pellet volume averaged temperatures and hot rod internal pressures calculated by the FATES3 code continue to be bounded by those values calculated with STRIKIN if the FATES3 code is ramped to the same LOCA initial power conditions used by STRIKIN? What are the power distributions used in STRIKIN? What are the fuel (centerline and surface) and cladding (inside and outside) temperatures corresponding to those results given in Section 8.3 of the Calvert Cliffs Unit 1, Cycle 6 Reload Report? Is this conclusion changed by the instantaneous fission gas release model in FATES3 or the burnup assumed for the calculation?

Response 2

Pellet volume averaged temperatures and hot rod internal pressures of FATES3 continue to be bounded with STRIKIN.

STRIKIN-II and FATES3 were used to calculate fuel temperatures and hot rod internal gas pressures for the same assumption of burnup, initial power level, and power distribution for verification. Table 2-1 lists the FATES3 and STRIKIN-II fuel temperatures and pin pressures predicted at two rod average burnups. In each case the same peak power and axial and radial power distributions were assumed. The data shown is not for CC-1, Cycle 6 but for identical fuel with a trapazoid axial power shape set at a peak of 10.46 kw/ft and an axial average of 9.39 kw/ft. The 4500 MWD/MTU data is typical of early in life fuel conditions. This corresponds to fully densified fuel, maximum fuel-clad gap size and hence the time of maximum stored energy in the fuel. The 25,500 MWD/MTU data is typical of end of cycle fuel conditions with high pin pressures, fuel-clad contact and relatively low stored energy in the fuel. For both conditions, a close correspondence between fuel centerline, fuel surface and volume average fuel temperatures is shown. The STRIKIN-II volume averaged temperatures are shown to be slightly higher than FATES3. The pin pressure is transferred directly from FATES3 to STRIKIN-II. Therefore, there is an exact correspondence of this parameter.

The power distributions used in STRIKIN-II for ECCS performance calculations have four basic components. First, a generic normalized axial power distribution is used for all C-E ECCS calculations having a 1.68 peaking factor at 65% of the core height. This generic axial shape was developed from sensitivity studies documented in CENPD-132-P and reviewed and approved by NRC for conservative application in C-E ECCS performance analyses. Second, the normalized radial distribution of heat generation rate in the fuel pellet is transferred as input directly from FATES3. Third, the absolute power generation in STRIKIN-II is defined by selecting a target peak linear heat rate (kw/ft) input specification for the peak power node. Fourth, fractions of total rod power generated in the pellet, clad and coolant are specified. These four components together yield a complete definition of the hot rod power distribution.

Table 2-2 lists the actual initial fuel and clad temperatures predicted by STRIKIN-II at 15.5 kw/ft at the two burnups discussed in Section 8.3 of the Cycle 6 reload report.

STRIKIN-II remains consistent with the fuel parameter predictions of FATES3 at all burnups and this conclusion is not changed by the instantaneous fission gas release model in FATES3.

TABLE 2-1

Comparison of FATES3 and STRIKIN-II

Fuel Parameter Predictions

Comparison @ 4500 mwd/mtu (Rod Average Burnup):

Code	Fuel Centerline Temp (F)	Fuel Surface Temp (F)	Volume Avg. Fuel Temp (F)	Pin Pressure (psia)
FATES3	2625	1058	1782	1178
STRIKIN-II	2624	1071	1793	1178

Comparison @ 25,500 mwd/mtu (Rod Average Burnup):

Code	Fuel Centerline Temp (F)	Fuel Surface Temp (F)	Volume Avg. Fuel Temp (F)	Pin Pressure (psia)
FATES3	2275	839	1495	1646
STRIKIN-II	2280	853	1508	1646

TABLE 2-2

STRIKIN-II Fuel Parameter

For Calvert Cliffs Unit I

Cycle 6

Burnup	Fuel Temperature (°F)			Clad Temp (F)		Pin Pressure
	Center Line	Surface	Vol Avg.	ID	OD	(psia)
3000 mwd/mtu	3634	1044	2213	767	663	1251
34000 mwd/mtu	3551	992	2127	766	663	2191

Question 3

Please supplement Section 2.4, "Application of fission gas release model to a variable fuel temperature history" in sufficient detail to permit programming of the model in an NRC fuel performance audit code.

Response 3

Combustion Engineering has developed a fission gas release model which uniquely accounts for variable power and temperature history. The new model accounts for gas release from individual regions of a fuel pellet (radial rings) and more properly calculates fission gas release rate based on the current unreleased fission gas inventory in each region. In addition, the mechanism of grain boundary sweeping which accompanies grain growth is recognized and the associated fission gas release modeled. C-E believes thisfeature to be particularly important in modeling fission gas release after a significant power increase. A description of the method by which C-E models the fission gas release equations described in CEN-161(B) is given below and is followed by a detailed example.

[

] These empirically derived curves are described by

[ ] (3-1)

where (3-1a)

(3-1b)

Terms are the same as defined in Section 2.2 of CEN-161(B). [

]

[ ]

Ignoring grain growth for the moment, the fission gas inventory is computed from Equation 3-1 using specific rules [ ] and then computing the release fraction from

$$[\quad] \qquad (3\text{-}2)$$

The rules necessary for application to a variable temperature history are:

1. [ ]

2 [ ]

3. [ ]

4. [ ]

If temperatures are sufficiently high for a period of time, grain growth occurs as described by Section 2.2 of CEN-161(B). If grain growth is predicted to occur during an increment of history, then an additional decrease in inventory (or gas release) is computed [ ] as described above. This decrease in inventory is given by

[ ] (3-3)

Terms are the same as defined by CEN-161(B). Rules applied when grain growth occurs are:

1. [ ]

2. [ ]

3. [ ]

[ ]

An example of cycling between two temperature levels T_1 and T_2 is given in Figure 3-1. [ ]

[

] The additional increments shown in the figure follow the same pattern.

Figure 3-1

FATES3 MODELING OF TEMPERATURE CYCLING BELOW TEMPERATURE FOR RESTRUCTURING (CONSTANT GRAIN SIZE)