August 11, 2000

Mr. T. A. Coleman, Vice President
Government Relations
Framatome Cogema Fuels
3315 Old Forest Road
P. O. Box 10935
Lynchburg, Virginia 24506-0935

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION - FRAMATOME TOPICAL REPORT BAW-10231P (TAC NO. MA6792)

Dear Mr. Coleman:

By letter dated September 16, 1999, Framatome Cogema Fuels requested a review of Topical Report BAW-10231P, "COPERNIC Fuel Rod Design Code." The staff has determined that additional information is needed in order to complete its review.

The enclosed questions have been discussed with Mr. F. McPhatter of your staff. Please provide a response to these questions within 30 days of receipt of this letter. If you have any questions concerning our review, please contact me at (301) 415-1321.

Sincerely,

***/RA/***

Stewart Bailey, Project Manager, Section 2
Project Directorate III
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Project No. 693

Enclosure: Request for Additional Information

cc w/encl: See next page

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**REQUEST FOR ADDITIONAL INFORMATION**

**TOPICAL REPORT BAW-10231**

**"COPERNIC FUEL ROD DESIGN CODE"**

1. Section 2.4 mentions iterations/convergence on gap conductance or contact pressure and also on axial interaction forces but does not mention an iteration on fissions gas released (FGR and # of moles), however, Figure 2-4 indicates that the code may iterate on number of moles released. Please discuss which is correct. If the code does not iterate on number of moles please discuss why this is satisfactory for code applications including transients.

2. Please compare the COPERNIC fuel thermal conductivity predictions to out-of-reactor $UO_2$ thermal diffusivity data from References 1 and 2 and any other high burnup diffusivity data that are applicable. The $UO_2$ diffusivity data can be converted to thermal conductivity for these comparisons using the COPERNIC equations for specific heat. In order to fully understand the rim model thermal conductivity as applied to Halden temperature predictions, please provide a one axial node calculation of temperature profile for IFA 562 at burnups of 60, 80 and 90 GWd/MTU with and without the rim model. Please provide the radial burnup profiles used for this calculation.

3. The temperature uncertainties for LOCA and fuel melt analyses should ideally be based on data at linear heat generator rates (LHGRs) $\geq$ 30 kW/m because these analyses are performed at high LHGRs. The problem with determining temperature uncertainties for burnups greater than 30 GWd/MTU is that there is very little measured centerline temperature data with LHGRs $\geq$ 30 kW/m. Please provide the COPERNIC comparisons to data by plotting predicted minus measured temperatures versus burnup for LHGRs $\geq$ 30 kW/m to determine whether there is a change in thermal uncertainty with increasing burnup, and provide the uncertainties from this data comparison. Also, provide the COPERNIC predicted minus measured centerline temperature data versus burnup for LHGRs $\geq$ 15 kW/m, and the uncertainties from this data comparison. These comparisons will help to verify that the uncertainties for the data that includes the lower LHGRs are applicable to the higher LHGRs where LOCA and fuel melting analyses are performed.

4. Please provide LHGRs and design information for the EXTRAFORT test rod.

5. The comparison to IFA 432-1 inlet thermocouple only extends to a burnup of 9 GWd/MTU, but the NUREG/CR-4717 report provides data up to a burnup of 27 GWd/MTU at the inlet thermocouple. Please provide the COPERNIC comparison up to the limit of the data or a justification why this comparison is not valid.

6. Is Framatome a member of Halden? If so, Halden has refabricated two high (~ 59 GWd/MTU) burnup rods (one with a functional thermocouple) and placed them first in IFA-597.2 (HWR-442) and subsequently in IFA- 597.3 (HWR-543) with measured centerline temperatures. Please compare COPERNIC code predictions to this data and include this data in the response to Question 3 above.

7. The athermal fission gas release model (Section 5.2.2) is dependent on open porosity but no values are provided for what is used for Framatome fuel. What values are used for open porosity? If more than one value is used, please provide the value for each fabrication process.

8. The Section 5.2.3.5 explanation is not very clear about how the fission gas release model applies to varying conditions of power and temperature. It would help to have several examples for conditions of both increasing temperature and decreasing temperature. Also, examples of fast and slow rate of change in fuel temperature are warranted. It appears that the resolution thickness is not used in the final equations in COPERNIC for computing fission gas release. Is this interpretation correct?

9. A comparison of the COPERNIC upperbound fission gas release predictions to measured data (with > 7 percent measured release) from $UO_2$ - $Gd_2O_3$ fuel rods with steady-state power operation (from Table 5-3) demonstrates that the code underpredicts 2 out of 6 rods (it is noted that one of the rods is only slightly underpredicted). A comparison of COPERNIC upperbound predictions to the transient measured data with >5 percent release from $UO_2$-$Gd_2O_3$ rods (from Table 5-4) demonstrates the code underpredicts 5 out of 25 rods. This indicates that the code's upperbound fission gas release model for $UO_2$ - $Gd_2O_3$ bounds much less than 95 percent of the data that are within the range of application for the rod pressure analysis. Also, the code does not appear to have been compared to the B&W segmented rodlets steady-state irradiated in ANO-1 and power ramped in the Studesvik R2 reactor. If not, why was this comparison not made and presented because these rods are representative of U.S. designs?

10. The standard deviation of the gaseous swelling model is on the order of the inferred gas porosity from the measured porosity distributions. In fact there are only 3 data points out of 14 that have inferred gaseous swelling greater than 0.6, i.e., significantly greater than the standard deviation. Of these 3 data points only one of these is predicted well by the gaseous swelling model while the other two data points are significantly underpredicted by factors of 1.6 and 2.9. Therefore, the validity and the accuracy of the gaseous swelling model appears questionable. What is the impact of the gaseous swelling model on rod pressure, melting and strain predictions? Does the gaseous swelling model use local burnup or pellet average burnup. The COPERNIC steady-state gaseous swelling model (Equations 6-13 to 6-15) has been programmed into FRAPCON-3 with calculational results of 0.007 inches of displacement at a pellet average burnup of 62 GWd/MTU with a centerline temperature of 1200°C. Is this predicted displacement with this model reasonable for these conditions? If not, further discussions are necessary to understand the gaseous swelling model.

11. Figure 6-8 (from September 1999 version) predicted versus measured densification data is significantly different from Figure 6-5 of the July 1998 version of COPERNIC; however, the densification and swelling models appear to be the same. Please explain why the data in the two figures are not the same.

12. The fuel column growth data in Figure 6-9 (September 1999 version) appears to contain significantly less growth data than the same figure (Figure 6-6) in the July 1998 version of COPERNIC. Please discuss why there is less data in the current version of

COPERNIC. Does the column growth data in Figure 6-11 include both ADU and AUC processed fuel or is it just AUC fuel?

13. Equation 7-1 for creep is a function of the shear stress component ($\sigma_\theta$ - $\sigma_r$). Please provide a derivation of how this shear stress is determined to be the only active determinant of creep from Hills or Von Mises equations because these are not the only shear stress or stress components in these equations.

14. Will the FRAGEMA AFA 2G cladding that is fabricated in Europe be used in U. S. plants? Sections 7.1.2.2.1 and 7.1.2.3.1 refer to a number of cladding tube (AFA 2G) irradiation tests in the SILOE test reactor. Please provide further information on the manufacturing differences between the cladding from these tests and those manufactured commercially for U. S. plants, e.g., FCF Base Zr-4 and AFA 2G. Also, were the hoop stresses quoted in Table 7-1 positive or negative? (The creep model needs to be validated against the current U.S. fabricated FCF Zr-4 cladding. See question 15.)

15. Section 7.1.2.3.2 and Figures 7-20, 21 and 22 all refer to creep data from fuel rods irradiated in the CAP test reactor. Pacific Northwest National Laboratory (PNNL) nor NRC is familiar with this test reactor. Please provide the test reactor or loop conditions that are pertinent to in-reactor creep such as coolant inlet-outlet temperatures, fast flux, system pressure, etc. Also, provide predicted versus measured creep for the FCF Zr-4 cladding used in the U.S. and the background information on this data.

16. Section 7.1.2.3.3 notes that creep data from one rod was excluded from the uncertainty determination because it was next to gadolinia rods. Does this mean that the creep model uncertainty does not apply to fuel rods near gadolinia rods? Also, Figure 7-20 shows a considerable amount of measured-to-predicted data that are outside of the uncertainty bounds proposed. Please discuss why it is ok to discard this data from the uncertainty determination for creep and those data in Figure 7-20 that are not within the proposed bounding creep uncertainty. Please identify those analyses where overprediction of creep is conservative and those analyses where underprediction is conservative.

17. Section 7.1.3.2.1 discusses the development of the M5 creep model from tube irradiations but no comparison to this data is provided, and the stress and temperature parameters of this data are also not provided. Please provide this data and comparisons to the M5 creep model. It is also stated that the secondary thermal creep rate is independent of alloy type, but no data is presented to corroborate this statement. Please provide this data.

18. Does COPERNIC consider the effects of cladding growth (Section 7.3.2) in the diametral direction or is this implicit in the creep data? Also, the upperbound model underpredicts a significant amount of growth data in Figure 7-50. Please explain why this is acceptable. The alloy 5 growth model, Equation 7-27, is not linearly dependent but has a decreasing slope with fluence while the majority of Zircaloy growth data show a linear dependence with fluence. In addition, an initial examination of Figure 7-54 appears to show that a linear dependent model would provide as good or better

prediction of the alloy 5 growth data compared to the model proposed. Please provide further information on why Equation 7-27 is more appropriate for predicting alloy 5 growth even though a linear model would be more conservative and provide as good a fit to the growth data.

19. Section 8.1 discusses the COPERNIC corrosion model and comparisons to data. The coolant inlet temperatures are provided for some of the reactors from which corrosion data was taken but coolant outlet temperatures and LHGR are also important parameters. What were the outlet temperatures and average LHGR/cycle for both the Zr-4 and alloy 5 data (including the adjustment rod data) and identify high duty, medium duty and low duty plants (see 20 below)? Section 8.1.3.2 states that the alloy 5 data is based on the maximum average azimuthal oxide thickness over the span height. Please discuss how this is determined from actual measurements, e.g., is it an average over a given length and how many azimuthal orientations are measured?

20. Also, oxide predictions and comparisons to data from Zr-4 are provided for all axial rod locations; however, NRC is most concerned with rod locations that experience maximum oxide thicknesses and corrosion from high duty plants. The axial locations with maximum oxide thicknesses are typically in the next to last span or the next to last two spans from the top of the assembly depending on the number of spacer grids per assembly. Please provide predicted minus measured oxide thickness versus both burnup and measured oxide thickness only for those axial spans with maximum measured oxide thickness for each rod, and identify high duty, medium duty and low duty plants along with a discussion of the differences between the operating parameters of these different plants.

21. From examination of Figure 8-11, the COPERNIC code appears to significantly underpredict a large amount of measured oxide data from U. S. plants with Zr-4 cladding. Please provide predicted minus maximum measured oxide thickness versus burnup and maximum measured oxide thickness only from rods from U. S. plants using both the COPERNIC and COROSO2 corrosion models. Please provide predictions of this same U. S. data using the COPERNIC upper bound corrosion model. PNNL's comparison of COROSO2 and COPERNIC corrosion models at various temperatures for both Zr-4 and alloy 5 has demonstrated that COROSO2 predicts the greater oxide thicknesses. Please discuss why this is acceptable.

22. What is the basis for the oxide layer thermal conductivity functions provided at the bottom of page 8-3? It appears that the oxide conductivity is determined based on the oxide surface temperature. Is this interpretation correct?

23. Please provide the average LHGR/cycle for the hydrogen pickup data provided in Figure 8-22. The applicability of using only 5 cycle data to estimate the hydrogen pickup fraction is questionable because there may be other factors (such as heat flux) in the 3 and 4 cycle data that results in the 5 cycle data giving the lowest hydrogen pickup fractions.

24. Please provide the background data for the fuel melting temperature relationship used by COPERNIC (Equations 10-11 and 12-2).

25. Section 12.0 notes that COPERNIC is used for initialization of core thermal-hydraulic codes. Please list those calculated COPERNIC parameters used for initialization and the specific applications of the thermal-hydraulic codes.

26. In Section 12.1.1 (page 12-2) under discussion on code uncertainties, it is noted that the code has an option that conservatively bounds the fissions gas release data and that this option is used to bound the fission gas release for the rod pressure predictions. However, there is a concern that this option will not bound the $UO_2$ - $Gd_2O_3$ data within the fission gas release range that is important to the rod pressure analysis for $UO_2$ - $Gd_2O_3$ rods (see Question 9 above) at the stated level of conservatism. Please discuss this issue further, particularly in relation to Question 9 above.

27. In Section 12.1.1 (page 12-3) under the discussion on transients, it is noted that plant specific operating data may be used to establish simulated transients. Please explain further by what is meant by sufficient plant operating data and provide an example.

28. There is a concern that the uncertainty factor provided in Equation 12-1 may be too small at the predicted operating temperatures (stored energy) calculated for LOCA initialization. Please discuss this issue further, particularly in relation to Question 3 above.

29. Are any of the example calculations provided in Section 12 for fuel cores with two 24 month cycles? It appears that there are no 24-month cycle results presented for the Mark BW-17 design. If so, please explain because it is anticipated that a large number of plants will be switching to 24-month cycles in the next few years.

30. The axial power distributions for the transients were found for the example licensing analyses, but the power distribution for the steady-state power operation were not found in the topical report. Please provide these axial power distributions. If there are more than 20 axial power profiles it would be helpful to condense the number down to 20 or less. Also, the steady-state power histories are only provided as plots versus burnup. Please provide these in tabular form to support the NRC audit calculation of these calculational examples?

31. Section 12.4.1 states that the cladding strain analyses will be run with ......and the gaseous swelling option turned off. Performing these analyses without gaseous swelling ......... produces more accurate predictions ..... at the very high local power levels that accompany these analyses. This appears to be contradictory to the comparisons to data in Figures 6-17, 6-18, and 6-19 that demonstrate that COPERNIC with gaseous swelling option turned on provides an adequate prediction of diametral strains. Please provide data and information that supports the conclusion that the exclusion of gaseous swelling in COPERNIC produces more accurate strain predictions.

32. Section 12.5 states that COPERNIC will be used to generate cladding creep collapse initial conditions and example rod pressure results are provided in Figures 12-34 and 12-35. Are there any other initial conditions provided by COPERNIC for the creep collapse analysis, e.g., cladding temperatures? If so, please provide predictions of these initial conditions.

References

1. Kinoshita, M. et al. 2000, "High Burnup Rim Project (II): Irradiation And Examination to Investigate Rim-Structured Fuel," *Proceedings of the ANS International Topical Meeting on LWR Fuel Performance, Park City, UT, April 10-13, 2000.*

2. J. Nakamura, et al. 1997, "Thermal Diffusivity Measurements of a High-Burnup $UO_2$ Pellet," in *Proceedings of the ANS International Topical Meeting on LWR Fuel Performance, Portland OR, March 2-6 1997.*