FRAMATOME ANP

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FRAMATOME ANP, Inc.

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Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Response to Request for Additional Information - BAW-10240(P), "Incorporation of M5 Properties in Framatome ANP Approved Methods," (TAC No. MB7553)

Ref.: 1. Letter, Drew Holland (NRC) to James Mallay (Framatome ANP), "Request for Additional Information - BAW-10240-P, 'Incorporation of M5 Properties in Framatome ANP Approved Methods' (TAC No. MB7553)," July 16, 2003.

In Reference 1, the NRC requested additional information to facilitate the completion of its review of the Framatome ANP, Inc. topical report BAW-10240(P), "Incorporation of M5 Properties in Framatome ANP Approved Methods." The response to this request is contained in the attachment to this letter. A proprietary and non-proprietary version of the attachment are included.

Framatome ANP, Inc. considers some of the information contained in the attachment to this letter to be proprietary. This information has been noted by enclosing it within brackets. The affidavit provided with the original submittal of the reference topical report satisfies the requirements of 10 CFR 2.790(b) to support the withholding of this information from public disclosure.

Very truly yours,

Jerald S Holm for

James F. Mallay, Director
Regulatory Affairs

Enclosures

cc: F. M. Akstulewicz
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Project 728

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Request for Additional Information on Topical Report BAW-10240(P), *Incorporation of M5 Properties in Framatome ANP Approved Methods*

Question 1

On page 4-1 of the topical report (TR), it mentions that the previously defined M5 model for creep was not used in RODEX2-2A. Please provide information about how the previously approved M5 creep model is not compatible with RODEX2.

Response 1

Creep equations for use with M5 were approved in reference 1 (page B-3) for application with the TACO3 fuel rod code and in reference 2 (page 7-6) for use in the COPERNIC fuel rod code. The TACO3 code uses an equation with thermal and irradiation components developed for Zircaloy and modified with an effective creep multiplier for M5. The COPERNIC code uses an equation for M5 with a thermal component with strain hardening and an irradiation component. These equations are both benchmarked to the circumferential strain of the cladding.

The RODEX2 equation was developed independently for Zircaloy and was submitted in reference 3 (page G-9). It is similar to the creep equation used in the COPERNIC code and additionally has a dependence on the anisotropic coefficients of the cladding. The use of anisotropic behavior results in a model which is easier to benchmark for axial elongation. The RODEX2 model uses measured M5 anisotropic coefficients, and like the other equations is benchmarked to the irradiated clad tangential strain.

The RODEX2 equation was utilized primarily because it required no change to the RODEX2 coding.

Question 2

On page 4-5 of the TR, please provide justification for rounding the alpha phase expansion coefficient in the axial direction down.

Response 2

The value being adjusted is a multiplier in the axial thermal expansion formula for the alpha phase range. Framatome ANP uses a corporate-wide materials property reference for M5 in which the multiplier is [ ]. Although this value is slightly lower than the multiplier of [ ], the impact of the change is only [ ]. The stated uncertainty in the coefficient of thermal expansion in the alpha phase is [ ] (page 4-6). This is well within the [ ] uncertainty in the correlation.

Question 3

Section 4.1.10 of the TR describes how the cladding emissivity was developed for the entire range of application. Provide additional information and justification on how the transition region was developed since it is not a smooth transition.

Response 3

The specified transition model (extension of the low temperature correlation upward and the high temperature correlation downward to their intersecting point) was chosen because it roughly produced the expected transition region shape and was straightforward to implement. While the transition chosen is not smooth at the intersection of the high temperature and low temperature correlations, it is continuous and does not introduce non-physical trends. This method is applicable and valid for the intended use and range of applicability and represents a more accurate representation of cladding emissivity than the previously approved method.

A constant emissivity value for all temperatures encountered in LOCA and safety analysis calculations (i.e., high temperature range) was previously approved for use with M5 in BAW-10227P-A. This previously approved modeling of emissivity for M5 cladding used a constant emissivity value of [ ] for all temperatures. The value of [ ] was derived by averaging the values of the high temperature M5 emissivity correlation over the temperature range from [ ]. The use of a constant value was justified in BAW-10227P-A as follows:

> "*... For the LOCA and Safety Analysis, emissivity is used to determine a portion of the fuel to clad gap heat transfer and in the evaluation of the radiation term in the cladding exterior heat transfer coefficient. Because radiation is not a dominant mechanism in either process, the emissivity is implemented as a constant, non-temperature dependent, variable. ... The only conditions under which the emissivity is of credible importance are those during which the cladding is approaching its peak temperature. Therefore, the emissivity to be used in the LOCA and Safety Analysis will be an average over a temperature range from 800 to 1500 K (980 to 2240 F)...*"

In the SER for BAW-10227P-A, page 5, Section 2.5, the NRC reviewer states,

> "*...Because cladding radiation heat transfer is not a dominant mechanism for a fuel rod and the variation of emissivity within the range of application is small, the use of the FCF constant value of cladding emissivity on LOCA and safety analyses is acceptable...*"

The previously approved constant value approximation was replaced in the high temperature range between [ ] to provide as accurate a model as possible. Framatome ANP also developed a correlation from measured data for M5 emissivity in the low temperature range for steady state applications. The low temperature correlation is applicable between [ ]. A correlation was not developed for the emissivity of M5 cladding in the intermediate temperature range between [ ]. In applying the more accurate low and high temperature correlations, it was necessary to provide values for emissivity in the cladding temperature region between the defined correlations. Therefore, the extension of the two correlations until they intersected was chosen.

For low temperature application (such as RODEX2 fuel rod burnup calculations) the radiation component of heat transfer from the fuel to the clad is small, and the clad temperature will generally not exceed the upper limit of the low temperature correlation. For LOCA calculations, radiation heat transfer between the fuel and clad is not a dominant contributor, particularly in the lower temperature region of the LOCA range of application. Therefore, during any portion of the LOCA calculation when the clad temperature is in the range of the transition region, radiation heat transfer is only a minor contributor to total gap heat transfer. Consequently, the emissivity value used for the cladding in the transition range is not of great significance to gap heat transfer.

Question 4

In Section 5.1.8 of the TR, it is stated that Equation 4.9 is assumed applicable to all temperatures of interest. Provide justification for this assumption. Additionally, please define the temperature range of interest.

Response 4

The temperature range of interest, discussed in Section 5.1.8 of BAW-10240, extends from post accident cold conditions, around 300 K, to the upper cladding temperature allowed for LOCA calculations; around 1500 K. Table 5.1 of BAW-10240 provides a comparison between the M5 Young's Modulus correlation, Equation 4.9, and the Zircaloy Young's Modulus correlation from MATPRO-11 for temperatures from 300 K to 1600 K. Over this range, the two correlations are well behaved and trend together. Either could easily be approximated as a simple linear function of temperature. The M5 correlation is directly supported by data to temperatures of around [ ]. The extension of the correlation to higher temperatures for accident analysis is based on general observations of data for various similar alloys, the close relationship of the M5 modulus and the Zircaloy modulus in the low temperature range, and the low importance of elastic expansion to accident evaluations in the high temperature range. The extension of the correlation was considered during the review of the M5 topical, Reference 1 Appendix K Section K.3, with the result that the extension of the correlation to temperatures up to 1500 K was approved.

References

4. BAW-10227(P)(A), *Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel*, Framatome Cogema Fuels, February 2000.

5. BAW-10231(P)(A), *COPERNIC Fuel Rod Design Computer Code*, Framatome Cogema Fuels, April 2002.

6. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, *RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model*, Exxon Nuclear Company, March 1984.