FRAMATOME COGEMA FUELS

July 31, 2000
GR00-088.doc

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Subject: Topical Report BAW-10231P, "COPERNIC Fuel Rod Design Computer Code," Chapter 13 MOX Applications.

References:
1. T. A. Coleman to NRC Document Control Desk, GR074.doc, January 22, 1998.
2. T. A. Coleman to NRC Document Control Desk, GR99-191.doc, September 16, 1999.
3. T. A. Coleman to NRC Document Control Desk, GR99-234.doc, December 2, 1999.

Gentlemen:

Reference 1 was the original submittal of the COPERNIC topical report BAW-10231P. References 2 and 3 transmitted the updated version of BAW-10231P. Chapters one through eleven of BAW-10231P were transmitted in Reference 2 and contain the details of the experimental database, models for thermal phenomena, gas release, strains, etc., comparisons with measured data, and user manual for uranium dioxide, urania-gadolinia, and mixed oxide (MOX) fuels. Chapter 12 was transmitted in Reference 3 and contains the Applications Methodology for uranium dioxide and urania-gadolinia fuels.

Reference 2 also indicated that an addendum to BAW-10231P to support application to mixed oxide (MOX) fuel would be submitted in August, 2000. This MOX Applications Methodology (Chapter 13) is enclosed with this letter. NRC review of the COPERNIC uranium submittals is underway. FCF hereby requests that the review of this mixed oxide submittal be done independently from the uranium portions and that a separate contract be assigned for the review of Chapter 13.

Fifteen copies of the proprietary version and twelve copies of the non-proprietary version are attached. Please replace pages xix and xx in the Table of Contents in BAW-10231P, and place the remaining pages (Chapter 13) at the end of the report.

In accordance with 10CFR2.790, it is requested that this report be considered proprietary. An affidavit supporting this request

FRAMATOME TECHNOLOGIES

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T008 1/12

is attached. In order to support the engineering activities associated with implementation of mixed oxide lead assemblies, NRC approval of COPERNIC for mixed oxide fuel is requested by July 31, 2001.

Very truly yours,

T. A. Coleman, Vice President
Government Relations

cc: J. S. Wermiel, NRC
S. L. Wu, NRC
R. Caruso, NRC
M. S. Chatterton, NRC
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cc: (w/o Attachment)
R. E. Martin, NRC
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AFFIDAVIT OF THOMAS A. COLEMAN

A. My name is Thomas A. Coleman. I am Vice President of Government Relations for Framatome Cogema Fuels (FCF). Therefore, I am authorized to execute this Affidavit.

B. I am familiar with the criteria applied by FCF to determine whether certain information of FCF is proprietary and I am familiar with the procedures established within FCF to ensure the proper application of these criteria.

C. In determining whether an FCF document is to be classified as proprietary information, an initial determination is made by the Unit Manager, who is responsible for originating the document, as to whether it falls within the criteria set forth in Paragraph D hereof. If the information falls within any one of these criteria, it is classified as proprietary by the originating Unit Manager. This initial determination is reviewed by the cognizant Section Manager. If the document is designated as proprietary, it is reviewed again by personnel and other management within FCF as designated by the Vice President of Government Relations to assure that the regulatory requirements of 10 CFR Section 2.790 are met.

D. The following information is provided to demonstrate that the provisions of 10 CFR Section 2.790 of the Commission's regulations have been considered:

(i) The information has been held in confidence by FCF. Copies of the document are clearly identified as proprietary. In addition, whenever FCF transmits the information to a customer, customer's agent, potential customer or regulatory agency, the transmittal requests the recipient to hold the information as proprietary. Also, in order to strictly limit any potential or actual customer's use of proprietary information, the substance of the following provision is included in all agreements entered into by FCF, and an equivalent version of the proprietary provision is included in all of FCF's proposals:

"Any proprietary information concerning Company's or its Supplier's products or manufacturing processes which is so designated by Company or its Suppliers and disclosed to Purchaser incident to the performance of such contract shall remain the property of Company or its Suppliers and is disclosed in confidence, and Purchaser shall not publish or otherwise disclose it to others without the written approval of Company, and no rights, implied or otherwise, are granted to produce or have produced any products or to practice or cause to be practiced any manufacturing processes covered thereby.

Notwithstanding the above, Purchaser may provide the NRC or any other regulatory agency with any such proprietary information as the NRC or such other agency may require; provided, however, that Purchaser shall first give Company written notice of such proposed disclosure and Company shall have the right to amend such proprietary information so as to make it non-proprietary. In the event that Company cannot amend such proprietary information, Purchaser shall, prior to disclosing such information, use its best efforts to obtain a commitment from NRC or such other agency to have such information withheld from public inspection.

Company shall be given the right to participate in pursuit of such confidential treatment."

(ii) The following criteria are customarily applied by FCF in a rational decision process to determine whether the information should be classified as proprietary. Information may be classified as proprietary if one or more of the following criteria are met:

a. Information reveals cost or price information, commercial strategies, production capabilities, or budget levels of FCF, its customers or suppliers.

b. The information reveals data or material concerning FCF research or development plans or programs of present or potential competitive advantage to FCF.

c. The use of the information by a competitor would decrease his expenditures, in time or resources, in designing, producing or marketing a similar product.

d. The information consists of test data or other similar data concerning a process, method or component, the application of which results in a competitive advantage to FCF.

e. The information reveals special aspects of a process, method, component or the like, the exclusive use of which results in a competitive advantage to FCF.

f. The information contains ideas for which patent protection may be sought.

The document(s) listed on Exhibit "A", which is attached hereto and made a part hereof, has been evaluated in accordance with normal FCF procedures with respect to classification and has been found to contain information which falls within one or more of the criteria enumerated above. Exhibit "B", which is attached hereto and made a part hereof, specifically identifies the criteria applicable to the document(s) listed in Exhibit "A".

(iii) The document(s) listed in Exhibit "A", which has been made available to the United States Nuclear Regulatory Commission was made available in confidence with a request that the document(s) and the information contained therein be withheld from public disclosure.

(iv) The information is not available in the open literature and to the best of our knowledge is not known by Combustion Engineering, Siemens, General Electric, Westinghouse or other current or potential domestic or foreign competitors of Framatome Cogema Fuels.

(v) Specific information with regard to whether public disclosure of the information is likely to cause harm to the competitive position of FCF, taking into account the value of the information to FCF; the amount of effort or money expended by FCF developing the information; and the ease or difficulty with which the information could be properly duplicated by others is given in Exhibit "B".

E. I have personally reviewed the document(s) listed on Exhibit "A" and have found that it is considered proprietary by FCF because it contains information which falls within one or more of the criteria enumerated in Paragraph D, and it is information which is customarily held in confidence and protected as proprietary information by FCF. This report comprises information utilized by FCF in its business which afford FCF an opportunity to obtain a

competitive advantage over those who may wish to know or use the information contained in the document(s).

THOMAS A. COLEMAN

State of Virginia)
) SS. Lynchburg
City of Lynchburg)

Thomas A. Coleman, being duly sworn, on his oath deposes and says that he is the person who subscribed his name to the foregoing statement, and that the matters and facts set forth in the statement are true.

THOMAS A. COLEMAN

Subscribed and sworn before me
this 31st day of July 2000.

Notary Public in and for the City
of Lynchburg, State of Virginia.

My Commission Expires 8/31/01

EXHIBITS A & B

EXHIBIT A

Topical Report BAW-10231P, "COPERNIC Fuel Rod Design Computer Code"
Chapter 13 - MOX Application

EXHIBIT B

The above listed document contains information which is considered Proprietary in accordance with Criterion a and b of the attached affidavit.

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COPERNIC

BAW-10231

July, 2000

COPERNIC Fuel Rod Design Computer Code
Chapter 13 - MOX Applications

Non Proprietary Version

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FRAMATOME COGEMA FUELS

13. MOX APPLICATION METHODOLOGY (UNITED STATES)

The U.S. Department of Energy (DOE) has recommended that a significant portion of the nation's surplus weapons-grade (WG) plutonium be disposed of by reconstituting the plutonium into mixed-oxide (UO_2-PuO_2, MOX) fuel rods and irradiating them in commercial light water reactors. The COPERNIC code, developed utilizing the extensive European experience with reactor-grade (RG) MOX fuels, will be used to perform fuel performance analyses for MOX fuel with weapons-grade plutonium in support of this Material Disposition Program.

The MOX fuel produced from weapons-grade material will be virtually identical to the fuel produced from reactor-grade material in terms of physical characteristics and performance. The manufacturing processes, plutonium isotopics, impurities, and pellet microstucture will be controlled to ensure this equivalence. The fabrication process will use the COGEMA/ BELGONUCLEAIRE-developed MIcronized MASter blend (MIMAS) process currently supplying MOX fuel to 32 reactors in Europe. The use of WG plutonium will significantly reduce the PuO_2 content of MOX fuel relative to RG material. The WG material is about 95% fissile, whereas the RG material contains significant amounts of absorber isotopes (Pu-240, Pu-242). Thus, MOX fuel from WG material will require Pu contents of 4% to 5% instead of the 8% to 9% for RG MOX. Gallium and other impurities will be effectively eliminated through the use of an aqueous polishing process step added to the manufacturing process being used to produce the WG MOX fuel. Due to the different isotopics, the WG material will have a fissile plutonium content about 50% greater than that of the RG plutonium. However, the master mix of UO_2 and PuO_2 will be adjusted from the 70/30 ratio typical of RG material, to 80/20 for the WG material to ensure that the fissile content of the plutonium-rich particles remains the same as the reactor grade material. Since the fission density and thus, the fission product concentration and distribution, will be comparable to the RG fuel, the WG fuel behavior will be consistent with that of the European experience base.

The COPERNIC fuel performance code will be used primarily as a design tool for light water reactor fuel rods – both low enriched uranium (LEU) as discussed in Chapter 12 and mixed oxide as discussed in this chapter. This chapter prescribes the application methodology and presents example calculational results of the COPERNIC code applied to MOX fuel. The same design criteria applied to LEU fuel in Chapter 12 will be used with the COPERNIC code to verify the acceptable performance of MOX fuel rod designs, namely:

> Fuel Rod Internal Gas Pressure: the internal gas pressure of the maximum pressure fuel rod in the reactor will be limited to a value below that which would cause (1) the fuel-cladding gap to increase due to outward cladding creep during steady-state operation and (2) extensive DNB propagation to occur.
>
> LOCA Initialization: LOCA initialization predictions will be input into LOCA evaluation models that are used to verify two principal LOCA criteria: (1) fuel rod fragmentation must not occur as a direct result of the blowdown loads, and (2) the 10 CFR Part 50 temperature and oxidation limits must not be exceeded.
>
> Fuel Melting: fuel melting during normal operation and anticipated operational

occurrences is precluded.

Cladding Strain: the maximum uniform hoop strain (elastic plus plastic) shall not exceed 1%; the impact of steady-state creep-down and irradiation growth is excluded.

Creep Collapse Initialization: cladding collapse is precluded during the fuel rod design life.

Cladding Peak Oxide Thickness: the cladding peak oxide thickness shall not exceed a best-estimate predicted value of 100 microns.

These design criteria satisfy the fuel cycle review recommendations defined in Reg. Guide 1.70 (4.4.1) and the licensing requirements defined in 10 CFR 50.46 and SRP 4.2.

The COPERNIC code will also be used to provide data for analyses that have no explicit basis in the regulations. These include best-estimate fuel temperatures for nuclear analysis codes such as NEMO (Ref. 13-1) and initialization data for core thermal-hydraulic codes such as LYNXT (Ref. 13-2). The COPERNIC code will also provide best-estimate fuel performance predictions for other similar analyses.

The manner in which the COPERNIC code will be applied to the fuel rod design criteria is discussed below.

13.1. Fuel Rod Internal Gas Pressure

13.1.1. Fuel Rod Internal Gas Pressure Methodology

The COPERNIC code will be used to predict fuel rod internal gas pressures that are used to verify that the fuel rod internal gas pressure design criteria are met. The following analysis method which is consistent with that described in Chapter 12 for UO_2 fuel will be used.

Bounding steady-state internal gas pressures will be determined from COPERNIC internal gas pressure predictions. These bounding pressures will be used with an approved fuel rod gas pressure criterion to determine the limiting internal gas pressure that will result in the onset of fuel-clad lift-off. The Fuel Rod Gas Pressure Criterion (Ref. 13-3) was approved for Zircaloy-4 cladding in July 1995 and extended to advanced alloy M5 cladding in November 1999 (Ref. 13-4). The bounding pressure used in this analysis is composed, at any given time-in-life, of a COPERNIC best-estimate predicted pressure plus a pressure uncertainty allowance. The pressure uncertainty allowance is composed of a COPERNIC code uncertainty allowance and allowances for fuel rod manufacturing variations.

[b.]

Steady state and transient power history effects will be evaluated with COPERNIC. The treatment of code uncertainties, manufacturing variations, power histories, and transients is described in detail below.

Code Uncertainties: The COPERNIC code contains [b.]

Nominal fuel rod design characteristics and thermal-hydraulic conditions that are similar to those listed in Tables 13-1 and 13-2, respectively, will be used in these evaluations.

Manufacturing Variations: The effects of fuel rod manufacturing variations will be included in the pressure uncertainty allowance. COPERNIC best-estimate cases will be run with nominal fuel rod design characteristics

[b.]

The COPERNIC cases used to generate the pressure allowances described above will contain cladding oxide formation and the additional following characteristics.

Power History: The rod average power history selected for the COPERNIC internal gas pressure analyses will vary according to the stage of the fuel cycle design process the analysis is supporting.

Fuel rod design analyses, for example, will be performed with

[b.]

Applications analyses performed to support fuel reload operations will

[b.]

The power histories used in the COPERNIC internal gas pressure analyses will contain transient effects which are defined below.

Transients: The power histories discussed above will include both Condition-I and Condition-II transients. A transient is defined as a temporary change in the local power level of a fuel rod.

A Condition-I transient may occur during normal operation or the maneuvering of a plant. Condition-I design transients will be used in the fuel rod internal gas pressure analyses. A Condition-I design transient bounds all transients that are expected to occur during normal operation. [b.] Condition-I design transients will be included in the COPERNIC power histories. [b.]

In addition, if the power history contains regions of low power operation (such as reactor coast-down), the Condition-I design transients will be placed at those times in life that are at or near full power operation. [b.]

This method of defining the Condition-I transients for the fuel rod internal gas pressure analyses will be applied to both UO_2 and MOX fuel rods.

[b.]

A Condition-II transient or Anticipated Operational Occurrence (AOO) is an event of moderate frequency. These events may result in a reactor trip but the plant will be capable of returning to operation. These events, by definition, will not propagate to cause a more serious event such as a Condition-III or IV event and are not expected to compromise the fuel rod integrity or cause an over-pressurization of the reactor coolant or secondary systems. The limiting power distributions that could occur during those Condition-II transients that would result in a fuel rod internal gas pressure increase

[b.]

This method of defining the Condition-II transients for the fuel rod internal gas pressure analyses will be applied to both UO_2 and mixed oxide fuel rods.

13.1.2. Fuel Rod Internal Gas Pressure Example

One typical fuel rod design is used for the example presented in this section. This fuel rod design, the Mark-BW/MOX1 (non-axial blanket) design, is representative of the planned design to be

employed in the partial-MOX core fuel cycles and is an adaptation of the Advanced Mk-BW fuel rod design. Partial-MOX fuel cycles utilize both LEU and MOX fuel assemblies in the reactor core.

The Mark-BW/MOX1 is a fuel rod designed for Westinghouse (17 x 17)-type plants. The fuel rod characteristics and thermal hydraulic conditions for this example are listed in Tables 13-1 and 13-2, respectively. Note that these tables contain [b.]

[b.] shown in Figure 13-1 was selected for the fuel rod internal gas pressure methodology example. [b.]

The transients [b.] that are applied to the power history envelope are presented in Table 13-3. These tables contain the following information for each transient: the [b.]

were determined for this example based upon the manufacturing variations criteria presented above: [b.]

The bounding fuel rod internal gas pressure that was predicted using the methodology defined above is shown in Figure 13-2.

13.2. LOCA Initialization

13.2.1. LOCA Initialization Methodology

The COPERNIC code will be used to generate LOCA initialization predictions. These predictions will be used for LOCA evaluation models such as the RSG LOCA EM (Ref. 13-5) for Westinghouse-type plants and the LOCA EM Topical Addendum for MOX fuel (to be submitted). [b.]

[b.] Eq. 13-1

The following method will be used to generate the LOCA initialization predictions.

Nominal fuel rod characteristics and thermal-hydraulic conditions will be used that are similar to those listed in Tables 13-1 and 13-2, respectively. The COPERNIC predictions will include cladding oxide formation. The rods will be analyzed with

[b.]

13.2.2. LOCA Initialization Example

An example of the [b.] obtained using the LOCA initialization methodology described above is presented for a typical MOX fuel rod design in Figure 13-4. [b.]

were used for this example.

13.3. Fuel Melt

13.3.1. Fuel Melt Methodology

The COPERNIC code will be used to predict the linear heat rates where the onset of fuel centerline melting occurs. Fuel melting is not permitted during normal operation or anticipated operational occurrences.

Centerline fuel melt analyses will be performed with COPERNIC best-estimate predictions and nominal fuel rod design parameters. [b.]

The best-estimate fuel melt temperature relationship for MOX fuel from Chapter 10 is:

[b.] Eq. 13-2

where:

T_m = best-estimate centerline fuel melt temperature, ^oC,

y = plutonium content weight fraction, and

Bu = pellet burnup, GWd/tM.

[b.]

[b.] Eq. 13-3

The following fuel melt analysis method will be used.

Nominal fuel rod characteristics and thermal-hydraulic conditions will be used that are similar to those listed in Tables 13-1 and 13-2, respectively. The COPERNIC predictions will include cladding oxide formation. The COPERNIC cases will be run

[b.]

13.3.2. Fuel Melt Example

An example of the local linear heat rate predictions obtained [b.] is presented for the typical MOX fuel rod design in Figure 13-6. [b.] were used for this example.

13.4. Cladding Strain

13.4.1. Cladding Strain Methodology

The COPERNIC code will be used to predict the local linear heat rates at which the cladding uniform hoop strains equal 1%. Cladding uniform hoop strain is limited to 1% during normal operation or anticipated operational occurrences. Cladding strain analyses will be performed with COPERNIC best-estimate predictions and nominal fuel rod characteristics across the range of operational burnups.

The cladding uniform hoop strains [b.]

The induced strain, therefore, is defined as:

[b.] Eq. 13-4

where:

ε_{hoop} = cladding uniform hoop strain,

[b.]

Cladding strain analyses will be performed in the following manner.

Nominal fuel rod characteristics and thermal-hydraulic conditions will be used that are similar to those listed in Tables 13-1 and 13-2, respectively. The COPERNIC predictions will include cladding oxide formation. The COPERNIC cases will be run [b.]

13.4.2. Cladding Strain Example

An example of the linear heat rates obtained where the cladding uniform hoop strain is 1% is presented for the typical MOX fuel rod design in Figure 13-6. [b.]

13.5. Creep Collapse Initialization

13.5.1. Creep Collapse Initialization Methodology

The COPERNIC code will be used to generate cladding creep collapse initialization predictions. These predictions will be input into cladding creep collapse analysis codes such as CROV (Ref. 13-6). Cladding collapse is not permitted during the fuel rod design life.

Cladding creep collapse predictions will incorporate conservatism [b.]

The following method will be used for generating the creep collapse predictions.

Nominal fuel rod characteristics and thermal-hydraulic conditions will be used that are similar to those listed in Tables 13-1 and 13-2, respectively. The COPERNIC predictions will include cladding oxide formation and these cases will be run [b.]

Creep collapse evaluations will be performed during the fuel rod design process. The power history envelopes selected for these evaluations would be expected to bound the operating power levels of all future fuel cycle designs without introducing excessive conservatism into the design process. The validity of these envelopes will be verified as part of the reload design analysis.

13.5.2. Creep Collapse Initialization Example

An example of the fuel rod internal gas pressures obtained with the creep collapse initialization methodology defined above is presented in Figure 13-7. [b.] that was used for this example is shown in Figure 13-1.

13.6. Cladding Peak Oxide Thickness

13.6.1. Cladding Peak Oxide Thickness Methodology

The COPERNIC code will be used to generate cladding peak oxide thickness predictions. The peak cladding oxide thickness will not be allowed to exceed a best-estimate predicted value of 100 microns.

The following method will be used to generate the cladding peak oxide thickness predictions.

Best-estimate values will be used for all predictions. Nominal fuel rod characteristics and thermal-hydraulic conditions will be used, similar to those listed in Tables 13-1 and 13-2, respectively. [b.] A sub-batch is defined as fuel assemblies within a given fuel batch that have the same make-up (fuel rod designs, plutonium content, etc.) and that are inserted and discharged from the core at the same time so that the fuel assembly residence times are identical. [b.]

The COPERNIC cladding oxide model was developed from European PWR data. The fuel rod designs for these reactors are generally similar to those used by FCF. The fuel cycle designs and cycle lengths of European reactors, however, often differ significantly from United States reactors. [b.]

to ensure that the model provides best-estimate predictions at the 100 micron level.

13.6.2. Cladding Peak Oxide Thickness Example

An example of the COPERNIC cladding peak oxide predictions obtained is presented in Figure 13-8. This example contains the predictions for both low-tin Zircaloy-4 and M5 advanced alloy claddings, and illustrates the cladding oxide thickness margin gains obtained with the M5 advanced alloy cladding. [b.] used for this example is shown in Figure 13-1.

REFERENCES

Ref. 13-1 BAW-10180-A, Rev. 1, *NEMO - Nodal Expansion Method Optimized*, March 1993.

Ref. 13-2 BAW-10156-A, Rev. 1, *LYNXT - Core Transient Thermal-Hydraulic Program*, August 1993.

Ref. 13-3 BAW-10183-A, *Fuel Rod Gas Pressure Criterion (FRGPC)*, July 1995.

Ref. 13-4 BAW-10227P-A, *Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel*, November 1999.

Ref. 13-5 BAW-10168P-A, Rev. 3, *B&W Loss-Of-Coolant-Accident Evaluation Model for Recirculating Steam Generator Plants*, December 1996.

Ref. 13-6 BAW-10084P-A, Rev. 3, *Program to Determine In-Reactor Performance of BWFC Fuel Cladding Creep Collapse*, July 1995.

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FIGURES

FIGURE 13-1 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-2 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-3 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-4 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-5 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-6 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-7 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

FIGURE 13-8 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]

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TABLES

TABLE 13-1 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle Fuel Rod Characteristics

[b.]

TABLE 13-2 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle Thermal-Hydraulic Conditions

[b.]

TABLE 13-3 Typical Mark-BW/MOX1 Partial-MOX Fuel Cycle

[b.]

[b.]