FRAMATOME

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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

Partial Response to RAI on Chapter 13 of BAW-10231P

Ref.: 1. Letter, Stewart Bailey (NRC) to T. A. Coleman (Framatome ANP), "Request for Additional Information – Chapter 13 of Framatome Topical Report BAW-10231P (TAC No. MA9783), May 14, 2001.

Ref.: 2. Letter, James F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Partial Response to RAI," NRC:01:033, July 27, 2001.

Ref.: 3. Letter, T. A. Coleman (Framatome ANP) to Document Control Desk (NRC), GR00-088, July 31, 2000.

In Reference 1 the NRC issued a request for additional information (RAI) on BAW-10231P, "COPERNIC Fuel Rod Design Code." This RAI included questions concerning both the UO2 and the MOX portions of the report. The UO2-related questions were responded to in Reference 2. Responses to the remaining questions, except number 8, for which analyses are still being conducted, are enclosed. Attachment 1 contains the proprietary version of the response and Attachment 2 the non-proprietary.

Framatome ANP considers some of the material in these responses to be proprietary. The affidavit provided with Reference 3, which transmitted Chapter 13 of BAW-10231 (on which this RAI is based) satisfies the requirements of 10 CFR 2.790(b) to support the withholding of this information from public disclosure.

Very truly yours,

James F. Mallay, Director
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Enclosures

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ATTACHMENT 2

PARTIAL RESPONSE TO 5/21/2001 REQUEST FOR ADDITIONAL INFORMATION

TOPICAL REPORT BAW-10231P, CHAPTER 13

"COPERNIC FUEL ROD DESIGN CODE"

MOX APPLICATIONS

Below are responses to several of the 1st-Round questions received on the COPERNIC MOX Addendum. Responses to Questions 6 & 7 have previously been provided. The response to Question 8 will be provided at a later date.

1. **It is recognized that weapons grade plutonium will be used for MOX for commercial application in the U.S. However, the isotopic plutonium ratios are significantly different between reactor grade (reprocessed LWR fuel) plutonium and weapons grade plutonium. Please provide the plutonium ratios for reactor grade and weapons grade plutonium and; also, the tabular values of pellet radial power profiles to be used for weapons grade plutonium and how these values were determined. If the reactor grade and weapons grade MOX radial profiles are proposed to be similar, provide the calculational results for both MOX types that demonstrate this conclusion.**

Response:

Typical values for fresh reactor grade (RG) and weapons grade (WG) plutonium isotopics are provided in Table 1. These isotopics vary for reactor grade fuel depending upon the reprocessed uranium fuel enrichment, burnup, and decay time.

COPERNIC contains internal tables for MOX fuel pellet normalized radial power profiles. These tables are a function of **[d.]** .

The maximum weapons-grade plutonium content of any fuel rod to be used in the Plutonium Disposition Program is six weight percent plutonium, and the initial licensed rod-average burnup limit requested will be 50 GWd/t. Radial power profiles for RG and WG MOX fuels are presented in Tables 2a and 2b respectively. These profiles were calculated with the APOLLO-II transport code[1,2].

[b., d.]

2. **Please provide the specifications (including nominal values) of oxygen-to-metal (O/M) ratio, PuO_2 particle size, and grain size specified for the U.S. commercial application.**

Response:

The weapons grade MOX pellet specification was developed based upon the current specification used in Europe in order to ensure the similar performance of MOX fuels and applicability of the European experience base.

Fabrication will use the COGEMA/BELGONUCLEAIRE-developed MIcronized MASter blend (MIMAS) process currently supplying MOX fuel to 32 reactors in Europe. MOX manufactured by the MIMAS process involves blending and milling of UO_2 and PuO_2 powders (master mix) and then dilution of the master mix with more UO_2 to reach the final Pu content. The products of this process are not as homogeneous as the UO_2 pellet on a micro-scale although they approximate to the same condition on a macro-scale. Microscopic examination of MOX pellets shows Pu finely dispersed in a UO_2 matrix and micron size islands of plutonium rich particles. The particles are not pure PuO_2 particles but master mix particles with a maximum Pu content determined by the ratio of UO_2 (80%) to PuO_2 (20%) in the master mix.

The specification for plutonium rich particles states that at least 95% of the plutonium rich particles shall have an effective diameter (square root of the grain surface area) of less than 100 μm, the mean plutonium rich particle distribution shall be less than 50 μm, and no pure plutonium grain shall be greater than 400 μm.

The average grain size of the UO_2 matrix shall be greater than 4 μm.

The limit on O/M ratio, calculated as O/(U + Pu + Am), is 1.98 to 2.01.

3. **For the experimental thermal MOX data, what were the O/M ratios used for code verification?**

Response:

The O/M values used in the code verification are presented below. They are the best definition of the actual fuel characterization, i.e. the fabrication values for lower burnup MOX (GRIMOX) and equilibrium values reached after irradiation of higher burnup MOX (IFA 610 & IFA 606).

[d.]

4. **For the MOX fission gas release data, please provide the nominal and range of PuO_2 particle size for the different experimental rods used for code verification?**

Response:

The mean particle diameter in the MIMAS ammonium uranyl carbonate (AUC) wet route process pellet lots used in surveillance programs was [d.] microns. The mean particle diameter in the MIMAS ammonium diuranate (ADU) wet route process pellet lot was [d.] microns.

Figure 1 shows the results of electron probe micro-analyses of the plutonium rich particle size distribution on two representative fuel batches of MOX AUC and ADU (TU2). The total plutonium content is plotted as a function of particle size. This shows that about [d.] of the plutonium in the pellet is contained within particles larger than [d.] microns for the MIMAS/ADU (TU2) fuel, and about [d.] for the MIMAS/AUC fuel. Current plans are to utilize UO_2 produced via the ADU process in the Weapons Grade MOX Program.

5. **The conductivity equation for unirradiated MOX (Eq. 4-44) defines the term, y, as Pu content in weight-percent, but it appears that this may be weight fraction. Please verify which unit is intended. If the Pu content is in weight fraction, the correction for Pu conductivity is small for 100 wt% PuO_2, which appears to be too low (see questions 6 and 8 below).**

Response:

The correct unit is weight fraction.

As indicated in Chapter 1 of the COPERNIC topical, COPERNIC is applicable to MOX fuels up to [d.] weight percent plutonium. However, the maximum plutonium content currently planned for weapons grade MOX fuels is less than 5 weight percent and will be limited to less than six weight percent.

MOX fuel is a heterogeneous mixture of UO_2 and PuO_2 with the bulk of the fuel matrix comprised of UO_2. This leads to a modest reduction in thermal conductivity for MOX fuels compared with UO_2 fuels, as demonstrated for the COPERNIC and other thermal conductivity relationships in the response to 1st-Round MOX Question 6.

9. **What are the gas production values (xenon, krypton and helium) used in COPERNIC for MOX. Justify their application to weapons grade Pu. Also, how are the release fractions for helium determined in the rod pressure analysis, LOCA analyses, and other analyses where it is important?**

Response:

COPERNIC uses **[**b., d**]**

The fission yield of stable Xe + Kr isotopes for thermal fission of U-235 is 24.99% and 25.29% for thermal fission of Pu-239[3].

Helium is generated in fuel matrices by alpha decay of trans-uranium nuclides, such as the Cm^{242} (n, alpha) reaction, and ternary fission, the former being the major source. Studies of helium behavior showed that the helium diffusion coefficient in UO_2 is several orders of magnitude larger than that of noble fission gases and that helium is highly soluble in UO_2 [4,5]. Helium is not released from the fuel as long as its content does not exceed the solubility limit, which depends on the helium partial pressure in the rod.

[b., d.**]**

Additionally, helium production in weapons grade MOX fuel is lower than that of reactor grade MOX fuel due to the lower initial Pu-240, Pu-241, and Am-241 content (see Table 1).

10. **Has Framatome (or other parties) examined the interface between MOX fuel and the cladding at high burnups to determine if there are any chemical reactions (such as Zr-oxide formation or other reactions) between the fuel and cladding?**

Response:

The interface between MOX fuel and the cladding has been thoroughly examined on ~20 radial ceramographic micrographs performed on high burnup (53 GWd/t) rods. A zirconia layer of up to 10-12 μm has been observed, which is comparable to that seen for uranium fuel at equivalent exposure. No other chemical reactions have been observed.

Table 1
Typical plutonium isotopics (wt %) for the most abundant isotopes

Plutonium Isotope	Weapons Grade	Reactor Grade
^{238}Pu	0.0	1.0
^{239}Pu	93.6	59.0
^{240}Pu	5.9	24.0
^{241}Pu*	0.4	10.0
^{242}Pu	0.1	5.0
^{241}Am*	0.0	1.0

*Amount varies with decay time.

Table 2a
Normalized Radial Power Profile for 6 Weight Percent Reactor Grade MOX

[b., d.]

Table 2b
Normalized Radial Power Profile for 6 Weight Percent Weapons Grade MOX

[b., d.]

Figure 1
Plutonium Rich Particle Size Distribution

[d.]

Figure 2
Helium Balance in MOX PWR Fuel Rods

[b., d.]

References

1. Stewart N. Bailey (NRC) to T. A. Coleman (Framatome Cogema Fuels), *Safety Evaluation of Topical Report BAW-10228P, "SCIENCE" (TAC No. MA4599)*, October 26, 1999.

2. Stewart A. Richards (NRC) to T. A. Coleman (Framatome Cogema Fuels), *Correction to Safety Evaluation of Topical Report BAW-10228P, "SCIENCE" (TAC No. MA4599)*, May 24, 2000.

3. JEF – PC, O.E.C.D./NEA Data Bank, Version 1, November, 1994.

4. W.A. Stark, *Helium release from PuO_2 microspheres*", Nuclear Metallurgy, Vol. 17, Part 2 (1970) 554.

5. R. W. Grimes, *Simulating the behaviour of inert gases in UO_2*, Fundamental Aspects of Inert Gases, Plenum Press, New York, 1991.