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 Supplemental Question on BAW-10238(P), Revision 1, "MOX Fuel Design Report."

Ref.: 1. Letter, James F. Mallay (Framatome ANP) to Document Control Desk (NRC), "Request for Approval of BAW-10238(P), Revision 1, 'MOX Fuel Design Report'," NRC:03:037, May 30, 2003.

Framatome ANP requested the NRC's review and approval for referencing in licensing actions the topical report BAW-10238, Revision 1, "MOX Fuel Design Report" in Reference 1. During a conference call with the NRC on March 4, 2004, additional information was requested on the topical report. Specifically, the NRC requested Framatome provide justification to support the gallium limit requested in Reference 1. Attached please find the response to this request.

Also included in the attachment are clarifications to Reference 1 on previously submitted material. The provided responses are non–proprietary.

Very truly yours,

James F. Mallay, Director
Regulatory Affairs

Enclosure

cc: M. C. Honcharik
R. E. Martin
Project 728

T010
Y601

Attachment A

Supplemental Question 6: *Section 3.2.2 provides evidence that gallium concentrations up to 120 ppb (120 ng of gallium per gram of plutonium) in the PuO_2 powder will not cause degradation of a fuel rod during irradiation. Section 8.3.1.2 asserts that higher concentrations, up to 300 ppb in the PuO_2 powder, would be acceptable for the lead assemblies, but it does not provide evidence to support that assertion. Please provide the supporting evidence.*

Response to Supplemental Question 6: Laboratory experiments indicate that gallium has little tendency to embrittle zirconium-base alloys. Grubb and Morgan (Reference SQ6.1) investigated thirty-five elements for potential embrittlement of Zircaloy-2. The program involved constant extension rate tension tests of Zircaloy-2 bars in gaseous environments of the various elements under investigation. The results were compared to those obtained from Zircaloy-2 bars tested under inert conditions. It was determined that calcium, strontium, yttrium, zinc, cadmium, and iodine could cause embrittlement in the Zircaloy-2, but there was no evidence that the other 29 elements, including gallium, caused embrittlement.

If it is nevertheless assumed that gallium will degrade nuclear fuel cladding, irradiation tests of MOX fuel rods by ORNL can be used to set a lower limit on the amount of gallium that is required to cause such degradation. ORNL has destructively examined MOX rods containing pellets with gallium contents in the range of about 1,000 to 5,000 ppb (Reference SQ6.2). These rods were irradiated under simulated PWR conditions in the Advanced Test Reactor (ATR) to 40 GWd/MThm (References SQ6.3 and SQ6.4). None of these rods have shown any detrimental or unexpected behavior.

The gallium concentrations in the ORNL fuel are greater than what is expected in MOX lead assemblies or batch fuel. Framatome ANP proposes to conservatively limit the total amount of gallium in a lead test assembly MOX fuel rod to less than the minimum total amount in the ORNL test rods discussed in the previous paragraph. The evaluation below determines a maximum gallium concentration in the PuO_2 power that will satisfy this limitation.

The fuel length of the ATR rodlet is nominally 6 inches; the fuel length of a commercial PWR rod is nominally 144 inches. Assuming each ATR rodlet contains at least 1,000 ppb gallium and that the diametral dimensions of the pellets and cladding are similar to those of commercial PWR fuel, the weight of gallium in each 6 inch ATR rodlet is 1,000 x 6 x Z, where 1,000 is the gallium concentration (ppb), 6 is the length of the rodlet (inches) and Z is a constant incorporating all other variables (pellet dimensions, density, correction factors for units, etc). Solving the following equation, the same weight of gallium would be present in a 144 inch PWR fuel stack if the gallium concentration in the pellets was 41.7 ppb gallium.

$$1{,}000 \times 6 \times Z = 41.7 \times 144 \times Z \qquad \text{(SQ6.1)}$$

Thus, based on the ORNL examinations of MOX rodlets irradiated in the ATR, the pellet gallium concentration could be increased to 41.7 ppb without affecting fuel performance. In addition, ORNL measured the gallium concentrations of some commercial PWR UO_2 pellets. Five pellets for each lot were analyzed. The average gallium concentration for each lot was less than 12 ppb (heavy metal basis). Since an acceptable gallium concentration in a MOX pellet is 42 ppb and the concentrations in UO_2 pellets are 12 ppb, the PuO_2 powder used in MOX pellets could contribute an additional 30 ppb gallium (= 42 ppb – 12 ppb) to the pellet with minimal risk of affecting the cladding performance. Thus, for a PuO_2 dilution factor in the finished MOX pellet of 20:1 or greater, a gallium concentration in the PuO_2 powder of 600 ppb is acceptable, based on the ORNL data.

Applying a safety factor of two to this value provides a recommended maximum gallium concentration in the PuO_2 powder of 300 ppb. This value, 300 ppb, is one that can be achieved with LANL-type polishing and is recommended for the lead assembly program.

It is noted that the ATR rodlets used Zircaloy cladding, whereas the Mark-BW/MOX1 assemblies will use M5® cladding. Both of these alloys consist of >98% zirconium with alloying elements primarily in isolated second-phase particles. Therefore, it is reasonable to expect that their resistance to degradation by gallium will be similar.

1. SQ6.1 W. T. Grubb and M. H. Morgan, III, "A Survey of the Chemical Environments for Activity in the Embrittlement of Zircaloy-2," *Zirconium in the Nuclear Industry (Fourth Conference)*, ASTM STP 681, American Society for Testing and Materials, 1979, pp.145-154.

2. SQ6.2 R. N. Morris et al., *MOX Average Power Test Fuel Pellet Initial Gallium Content*, ORNL/MD/LTR-182, March 2000.

3. SQ6.3 R. N. Morris et al., *MOX Test Fuel 40 GWd/MT PIE: Final Report*, ORNL/MD/LTR-241, Volume 1, August 2003.

4. SQ6.4 S. A. Hodge et al., *Implications of the PIE Results for the 40-GWd/MT-Withdrawal MOX Capsules*, ORNL/MD/LTR-241, Volume 2, September 2003.

Clarifications of Reference 1 from previously submitted material:

Section 8.0: To clarify the hot cell examination schedule, FANP has added the following sentence to the third paragraph of this section and revised the fourth paragraph to read:

> "A destructive hot cell examination on selected rods from the lead assemblies will be performed following the second cycle.
>
> A third cycle of irradiation is proposed for selected lead assemblies to confirm MOX fuel performance to fuel rod burnups approaching 60,000 MWd/MThm. The irradiation will be followed by an extended poolside PIE."