July 26, 2011

MEMORANDUM TO: Travis L. Tate, Chief
Dose Assessment Branch
Division of Risk Assessment
Office of Nuclear Reactor Regulation

FROM: Anthony J. Mendiola, Chief **/RA/**
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SUBJECT: TECHNICAL BASIS FOR REVISED REGULATORY GUIDE 1.183 (DG-1199) FISSION PRODUCT FUEL-TO-CLADDING GAP INVENTORY

The purpose of this memorandum is to document the technical basis for revised fission product fuel-to-cladding gap inventories within Section 3.2 of Regulatory Guide (RG) 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors." Specifically, the non-Loss-of-Coolant Accident (non-LOCA) fission-product gap inventories listed in Section 3.2 of RG 1.183 and used to assess the radiological consequences for the fuel handling accident, pressurized water reactor (PWR) locked rotor event, PWR sheared shaft event, PWR steam line break event, PWR control rod ejection event, and boiling water reactor (BWR) control blade drop event. Attachment 1 provides proposed revisions to Section 3.2 of RG 1.183. Attachment 2 contains a Pacific Northwest National Laboratory (PNNL) technical report which supports the recommended RG revisions.

In a memorandum dated February 10, 2009 (ML0903602560), the Nuclear Performance and Code Review Branch (SNPB) provided recommended changes to Section 3.2 of RG 1.183. These changes were incorporated and the draft RG was issued as DG-1199. Extensive public comments were received which prompted revision to the RG and supporting technical basis document. Comment resolution tables have been completed and provided informally to AADB. Attachment 1 provides the proposed revision to Section 3.2 of DG-1199 (RG 1.183). enclosure 2 contains the revised PNNL technical report which supports the recommended changes and provides a detailed analytical procedure for calculating gap fractions (Appendix C to PNNL-18212 Revision 1).

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In summary, the following revisions to DG-1199 are proposed:

- In response to public comment, text was added to Section 3.2 clarifying the applicability of Table 1, 2, 3, and 4 as well as the treatment of fuel melt during reactivity initiated accidents (RIA). Guidance from RG 1.183 returned to Appendices C and H.

- In response to public comment, bounding fuel rod power profiles were extended. This necessitated a re-calculation of the fission product gap inventories. As part of this effort, peak nodal power (Fq) was replaced with rod average power (Fr) which is a better qualifier for fission gas release along the entire fuel stack and overall gap inventory.

    - Table 3 non-LOCA fission product gap inventories updated.
    - Table 4 RIA combined fission product gap inventories updated.

- Analytical method for predicting I-132 inventory revised to more accurately capture precursor Te-132 effects.

- In response to public comment, an acceptable analytical technique for calculating non-LOCA fission product gap inventories based upon specific fuel rod designs or more realistic fuel rod power histories was documented (Appendix C to PNNL-18212 Revision 1).

Since the earlier memo (and end of DG-1199 public comment period), the American Nuclear Society approved the new gas release model used in the development of the revised Table 3 fission-product inventories - ANSI/ANS-5.4-2011 standard, “Method for Calculating the Fractional Release of Volatile Fission Products from Oxide Fuel” (revision of withdrawn standard ANSI/ANS-5.4-1982, approved May 19, 2011).

Enclosure:
As stated

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Proposed Revisions DG-1199

Revised Section 3.2

Enclosure 1

3.2 Release Fractions[1]

For loss-of-coolant DBAs, Table 1 (for BWRs) and Table 2 (for PWRs) list the core inventory release fractions, by radionuclide groups, for the gap release and early in-vessel damage phases. These fractions are applied to the equilibrium core inventory described in Regulatory Position 3.1.

For non-LOCA DBAs other than reactivity initiated accidents (RIAs), where only the cladding is postulated to be breached, Table 3 gives the fractions of the core inventory for the various radionuclides assumed to be in the gap for a fuel rod. The release fractions from Table 3 are used in conjunction with the calculated fission product inventory calculated with the maximum core radial peaking factor. The licensing basis of some facilities may include non-LOCA events that assume the release of the gap activity from the entire core (e.g., heavy load drop accident). For events involving the entire core, the core-average gap fractions of Tables 1 and 2 may be used and the radial peaking factor may be omitted.

For RIAs, such as BWR control rod drop accident and PWR control rod ejection accident, the total fraction of fission products available for release equals the steady-state fission product gap inventory in Table 3 plus the transient fission product release resulting from the rapid power excursion. Table 4 lists the combined fission product inventory, by radionuclide groups, available for release from a fuel rod during a RIA. The transient fission product release component is presented as a function of increase in radial average fuel enthalpy (ΔH, cal/g). This component of the overall fission product inventory may be calculated separately for each axial node which experiences the RIA power pulse and then combined to yield the total transient fission product release for a particular fuel rod. The sum total of combined fission product inventories from each fuel rod predicted to experience cladding failure (all failure modes) should be used in the dose assessment.

The applicability of Table 3 non-LOCA fission product gap fractions is limited to fuel rods with a peak rod average power history below the bounding power envelope depicted in Figure 1. Appendix K provides an acceptable analytical technique for calculating non-LOCA fission product gap inventories based upon specific fuel rod designs or more realistic fuel rod power histories. Reference 18 documents the methods used to calculate the Table 3 and Table 4 fission product inventories, including application of modeling uncertainties.

The non-LOCA fission product gap inventories listed in Table 3 and RIA combined release fractions listed in Table 4 do not include the additional contribution associated with fuel melting. Guidance for adjusting these gap inventories for fuel rods which are predicted to experience limited fuel centerline melting is provided in the event-specific appendices.

Table 1 BWR Core Inventory Fraction Released into Containment Atmosphere

1 The NRC has determined the release fractions listed here to be acceptable for use with currently approved LWR fuel. The data in this section are not applicable to cores containing mixed oxide (MOX) fuel.

{ No Change}

Table 2 PWR Core Inventory Fraction Released into Containment Atmosphere

{ No Change}

Table 3 Non-LOCA Fraction of Fission Product Inventory in Gap

Group	Fraction
I-131	0.08
I-132	0.09
Kr-85	0.38
Other Noble Gases	0.08
Other Halogens	0.05
Alkali Metals	0.50

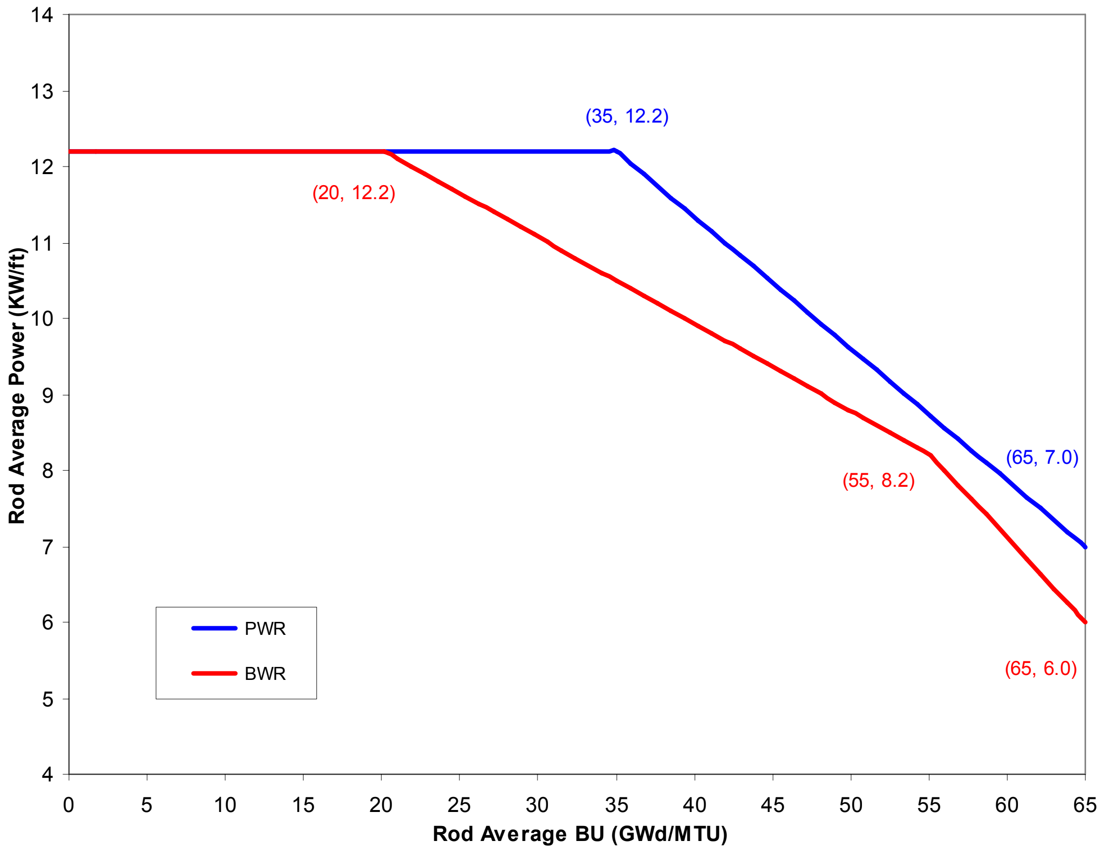
Table 4 Fraction of Fission Product Inventory Available for Release from Reactivity Initiated Accidents

Group	Combined Release Fraction[2,3]
I-131	((0.08) + (0.00073 * ΔH))
I-132	((0.09) + (0.00073 * ΔH))
Kr-85	((0.38) + (0.0022 * ΔH))
Other Noble Gases	((0.08) + (0.00073 * ΔH))
Other Halogens	((0.05) + (0.00073 * ΔH))
Alkali Metals	((0.50) + (0.0031 * ΔH))

2 ΔH = increase in radial average fuel enthalpy, cal/g

3 Calculated values of combined release are limited to a value of 1.0.

Figure 1 Maximum Allowable Power Operating Envelope for Non-LOCA Gap Fractions



PNNL Technical Report:

Update of Gap Release Fractions for Non-LOCA Events

Utilizing the Revised ANS 5.4 Standard

C. E. Beyer
P. M. Clifford

Revision 01

June 2011

ENCLOSURE 2