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MEMORANDUM TO: Robert Lukes, Chief
Nuclear Performance and Code Review Branch
Division of Safety Systems

FROM: Paul Clifford, Senior Technical Advisor **/RA/**
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SUBJECT: REVISED TECHNICAL BASIS FOR FISSION PRODUCT RELEASE FRACTIONS

The purpose of this memorandum is to document the technical basis for recommended updates to the existing set of fission product release fractions. Table 3 of Regulatory Guide (RG) 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors*, provides fission product inventories within the void volume of the fuel rod for several different radionuclide groups. These radiological source terms are acceptable for use in predicting radiological consequences during postulated non-loss-of-coolant accidents, including 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. Footnote 11 of RG 1.183 defines limitations on the applicability of these release fractions including a limit on peak rod average power of 6.3 kw/ft above
54 GWd/MTU rod average burnup. Advancements in fuel design and utilization have exceeded this applicability limit, prompting many utilities to submit license amendment requesting approval for new fission product release fractions.

To support modern fuel design and utilization, the staff, along with the assistance of Pacific Northwest National Laboratory (PNNL), embarked on a program to expand the applicability window of the fission product release fractions. In 2009, the staff completed FRAPCON-3.3 calculations for a new set of release fractions with a broader range of applicability. The revised release fractions were documented in a memo dated February 10, 2009 (ML0903602560). Changes were incorporated in RG 1.183 and the draft RG was issued as Draft Guide (DG) -1199. Extensive public comments were received which prompted revision to DG-1199 and it's supporting technical basis document. The revised release fractions were documented in a memo dated July 26, 2011 (ML111890397).

Since 2011, there have been significant upgrades to the FRAPCON fuel rod thermal/mechanical performance models. In addition, the Fuel Analysis under Steady-state and Transients (FAST) fuel rod code which incorporates both steady-state FRAPCON models and transient FRAPTRAN solutions was released. To ensure that the modified set of release fractions remain applicable, the staff decided to repeat the 2011 FRAPCON-3.3 calculations with the most up-to-date version of FAST.

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FAST Fission Product Release Factions

PNNL Report PNNL-18212, Revision 1, *Update of Gap Release Fractions for Non-LOCA Events Utilizing the Revised ANS 5.4 Standard* (ML111890397), documents an acceptable analytical procedure for calculating radionuclide release fractions along with bounding values to replace the proposed DG-1199 Table 3 and 4 source terms. Following this analytical procedure and using identical fuel rod parameters and power histories, the original FRAPCON-3.3 calculations were repeated using FAST. See Appendix A of the PNNL report for fuel design specifications and rod power histories. For completeness, the fuel rod power profiles are provided in Figure 1 below. During this exercise, the staff identified a few discrepancies in the FRAPCON-3.3 input decks which impacted the BWR fuel rod power history and the PWR axial power profiles. Correcting for these discrepancies resulted in a reduction in the BWR short-lived and long-lived release fractions and an insignificant change to the PWR release fractions.

Figure 1: Fuel Rod Power Operating Envelopes

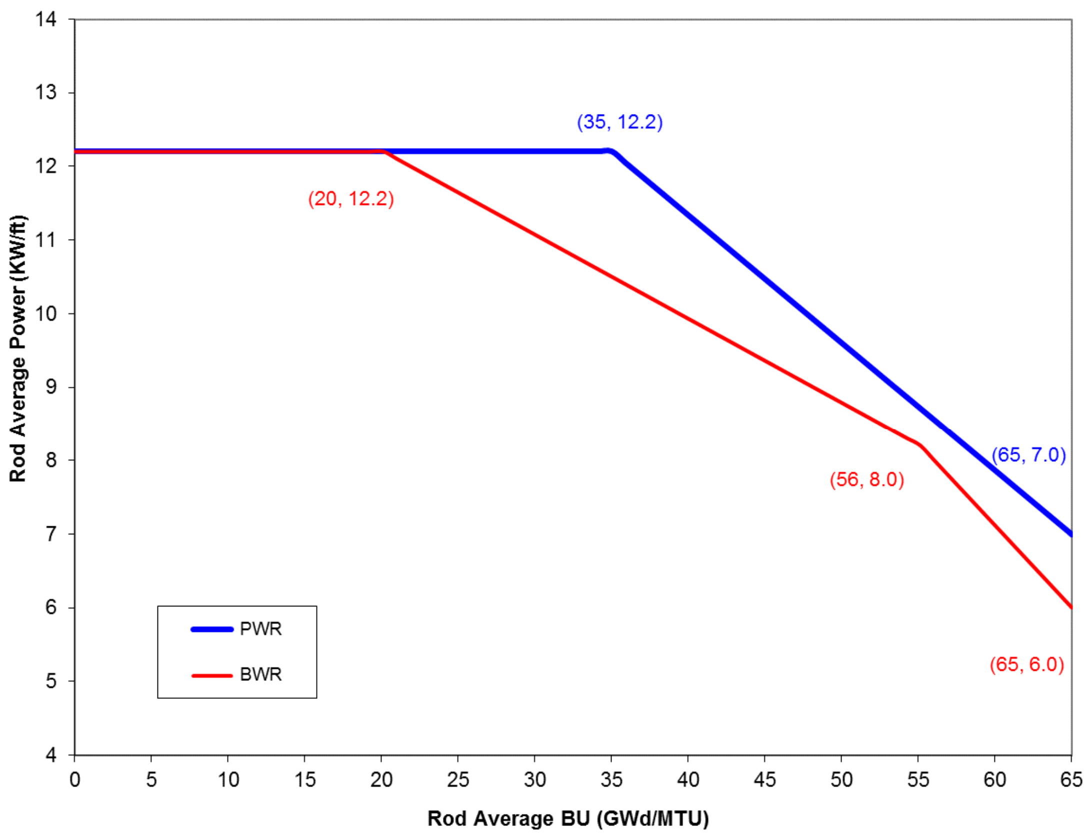

Table 1 lists the results of these FAST calculations for the limiting PWR fuel rod configuration along with a comparison to the 2011 FRAPCON-3.3 results. The maximum calculated release fractions from the seven segmented power histories (SPH) at a 95/95 probability/confidence level are reported in the table. Both calculations predict the maximum long-lived release fractions near end-of-life at SPH#6 and the maximum short-lived release fractions closer to the knee in the power profile at SPH#4. As expected, the long-lived stable nuclide release fractions slightly increased due to the enhanced models within FAST. Changes in the algorithms implementing the 2011 ANS standard prompted differences shown for the short-lived release fractions. Note that actual difference in Kr-85m release fractions were less than 0.002 (absolute); however, these differences were exaggerated by the application of an uncertainty factor of 5.0 (in accordance with ANS-5.4 standard).

Table 1: PWR Release Fractions

Nuclide	Half-Life	**FAST 2019 Calculated (95/95)**	FRAPCON3.3 2011 Calculated (95/95)	Difference (%)
Xe-133	5.243d	**0.0509**	0.0729	-43.4
Xe-135	9.10h	**0.0291**	0.0417	-43.4
Xe-135m	15.3m	**- -**	- -	
Xe-137	3.82m	**- -**	- -	
Xe-138	14.1m	**- -**	- -	
Xe-139	39.7s	**- -**	- -	
Kr-85	10.76y	**0.3624**	0.3571	1.5
Kr-85m	4.48h	**0.0224**	0.0321	-43.4
Kr-87	1.27h	**0.0116**	0.0167	-44.0
Kr-88	2.84h	**0.0158**	0.0228	-44.0
Kr-89	3.15m	**- -**	- -	
Kr-90	32.3s	**- -**	- -	
I-131	8.04d	**0.0535**	0.0768	-43.4
I-132	2.28h	**0.0604**	0.0866	-43.4
I-133	20.8h	**0.0322**	0.0461	-43.4
I-134	52.6m	**- -**	- -	
I-135	6.57h	**0.0230**	0.0330	-43.4
Cs-134	2.07y	**0.4871**	0.4776	1.9
Cs-137	30.1y	**0.4871**	0.4776	1.9

Table 2 lists the results of these FAST calculations for the limiting BWR fuel rod configuration along with a comparison to the 2011 FRAPCON-3.3 results. The maximum calculated release fractions from the seven segmented power histories (SPH) at a 95/95 probability/confidence level are reported in the table. Both calculations predict the maximum long-lived release fractions near end-of-life at SPH#6 and the maximum short-lived release fractions closer to the knee in the power profile at SPH#3. The decrease in release fractions for the stable, long-lived nuclides is due to the corrected rod power profile. As with the PWR results, differences in the volatile, short-lived nuclides release fractions were small (less than 0.002, absolute), but exaggerated by the application of the 5.0 uncertainty factor.

Table 2: BWR Release Fractions

Nuclide	Half-Life	**FAST 2019 Calculated (95/95)**	FRAPCON 2011 Calculated (95/95)	Difference (%)
Xe-133	5.243d	**0.0289**	0.0490	-69.7
Xe-135	9.10h	**0.0165**	0.0280	-69.7
Xe-135m	15.3m	**- -**	- -	
Xe-137	3.82m	**- -**	- -	
Xe-138	14.1m	**- -**	- -	
Xe-139	39.7s	**- -**	- -	
Kr-85	10.76y	**0.3284**	0.3721	-13.3
Kr-85m	4.48h	**0.0127**	0.0216	-69.7
Kr-87	1.27h	**0.0066**	0.0113	-70.5
Kr-88	2.84h	**0.0090**	0.0153	-70.9
Kr-89	3.15m	**- -**	- -	
Kr-90	32.3s	**- -**	- -	
I-131	8.04d	**0.0304**	0.0516	-69.7
I-132	2.28h	**0.0343**	0.0582	-69.7
I-133	20.8h	**0.0183**	0.0310	-69.7
I-134	52.6m	**- -**	- -	
I-135	6.57h	**0.0131**	0.0222	-69.7
Cs-134	2.07y	**0.4390**	0.4988	-13.6
Cs-137	30.1y	**0.4390**	0.4988	-13.6

Table 3 provides recommended gap release fractions for the major nuclide groups, along with a comparison to previously published values. Release fractions for the stable, long-lived nucli'des have not changed significantly since DG -1199 was published in 2009. However, these release fractions are markedly higher than the original RG 1.183 values. This change is driven by the expanded fuel rod power history and application of high confidence uncertainty factors. With respect to the volatile, short-lived nuclides, application of the 2011 ANS-5.4 standard allows the retention of the original release fractions even with the expanded fuel rod power history and application of high confidence uncertainty factors.

Table 3: Recommended Gap Release Fractions

Nuclide Group	**RG 1.183 (2000)**	**DG-1199 (2009)**	**PNNL-18212 Rev.1 (2011)**	**FAST Calculations (2019)**	**Recommended Values**
Kr-85	0.10	0.35	0.38	0.3624	0.36
I-131	0.08	0.08	0.08	0.0535	0.08
I-132	- -	0.23	0.09	0.0604	0.06
Other Nobles	0.05	0.04	0.08	0.0509	0.05
Other Halogens	0.05	0.05	0.05	0.0322	0.05
Alkali Metals	0.12	0.46	0.50	0.4871	0.49

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