Westinghouse

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Subject: Transmittal of Westinghouse Electric Company Comments on draft regulatory guide DG-1327 [Docket ID NRC-2016-0233]

Westinghouse Electric Company (Westinghouse) appreciates the opportunity to comment on draft regulatory guide DG-1327, "Pressurized Water Reactor Control Rod Ejection and Boiling Water Reactor Control Rod Drop Accidents," July 2019. The enclosure of this letter contains several editorial and technical comments. Westinghouse appreciates the NRC staff's consideration of the comments in the enclosure.

This submittal does not contain information proprietary to Westinghouse.

Correspondence with respect to this transmittal should be addressed to Korey L. Hosack, Manager, Licensing, Analysis, & Testing, Westinghouse Electric Company, 1000 Westinghouse Drive, Building 1, Suite 133, Cranberry Township, PA 16066.

Westinghouse worked with the Nuclear Energy Institute (NEI) regarding draft regulatory guide DG-1327 and would appreciate the NRC's consideration of their comments.

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Enclosure 1: Westinghouse Comments on DG-1327

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Office of Administration, Mail Stop: TWFN-7-A60M, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, ATTN: Program Management, Announcements and Editing Staff.

Westinghouse Comments DG-1327

1. Clarification on Limit Applicability in Section 1.1.1 [1]:

Section 1.1 stated that "The applicability of this guidance is limited to approved LWR fuel rod designs comprising slightly enriched uranium dioxide (UO_2) ceramic pellets (up to 5.0 wt% uranium-235) within cylindrical zirconium-based cladding, including designs with or without barrier lined cladding, an integral fuel burnable absorber (e.g., gadolinium), or a pellet central annulus."

Section 1.1.1 stated that "The applicability of this guidance to future LWR fuel rods designs (e.g., doped pellets, changes in fuel pellet microstructure or density, changes in zirconium alloy cladding microstructure or composition, coated zirconium alloy cladding) will be addressed on a case-by-case basis."

Comment: It is suggested that Section 1.1.1 be modified as "The applicability of this guidance to LWR fuel rod designs, different from the UO_2 fuel rod designs described in Section 1.1 (e.g., doped pellets, changes in fuel pellet microstructure or density, changes in zirconium alloy cladding microstructure or composition, coated zirconium alloy cladding), will be addressed on a case-by-case basis."

The doped pellets and changes in zirconium alloy have been used already in light water reactor (LWR) fuel designs. Some of those fuel designs have been previously addressed and approved as similar to the UO_2 fuel rod design, such as the **Optimized ZIRLO™** fuel cladding [2].

2. Clarification on Section 1.2.2 [1]:

In this section it states: "The recrystallized annealed (RXA) PCMI cladding failure threshold curves apply to cladding that has undergone final thermal treatment that produces an RXA metallurgical state, while the stress relief annealed (SRA) PCMI cladding failure threshold curves apply to cladding that has undergone final thermal treatment that produces an SRA metallurgical state. For any other metallurgical condition, the licensee or applicant should justify its similarity to either the SRA or RXA metallurgical condition."

Comment: Westinghouse **Optimized ZIRLO** high performance cladding [2], which has a partial recrystallized anneal (pRXA) final heat treatment, currently represents the majority of reload pressurized water reactor (PWR) fuel in the United States (US). Therefore, this significant population of US PWR fuel does not have defined cladding failure criteria under the draft guide.

Westinghouse has supporting documentation, which can be readily provided or audited upon request, that demonstrates that the trend in cladding ductility as a function of hydrogen, hydrides distribution after irradiation, and hydride reorientation behavior under stress are similar for **ZIRLO®** and **Optimized ZIRLO** cladding. This data supports a position that **Optimized ZIRLO** cladding should have similar reactivity initiated accident (RIA) cladding failure limits as **ZIRLO** cladding. A significant part of this data has been previously submitted as part of the PAD5 licensing [3] and in public domain papers [4].

Westinghouse requests that the proposed pellet-clad mechanical interaction (PCMI) cladding failure criteria for SRA **ZIRLO** cladding be applicable to pRXA **Optimized ZIRLO** cladding. If the NRC needs time to review the **Optimized ZIRLO** cladding data, then the Reg Guide should be delayed until that review is complete to ensure that the final guidance is applicable to the fuel products currently in many US PWRs.

3. Request for Clarification on High Temperature Cladding Failure Threshold Documented in Section 3.1 [1]:

Westinghouse has the following question and comments on the cited text:

Please clarify the technical basis of the 5% power level for the switch between the PCMI failure criterion and the high temperature cladding failure criterion. Some examples of how the limit switch at the 5% power could lead to confusing applications of the limits are provided below.

- Rod ejections initiated at 4.99% and 5.01% rated thermal power (RTP) would have a very similar transient response, but the analysis limits would be vastly different due to the criterion switch at the 5% power level specified in DG-1327. It is also possible that in some plant analyses, the RIA cases initiated at power lower than 5% could be more limiting than the 5% power case with respect to departure from nucleate boiling (DNB) as the high temperature fuel failure criterion.

- For two plants identical in every respect except for their rated power (for example, one had been uprated), 5% power would be a different megawatt (MW) for each plant, and yet these different absolute powers would require being compared to the same limit for the same fractional power level rod ejection simulation. Rod ejection transients of two identical plants initiated from the same absolute power should be compared to the same limit, regardless of the rated thermal power.

If no high temperature cladding failure has ever been observed during the period of a prompt criticality (e.g., within one second from the time of the peak power occurrence), then the PCMI limit should be used when an ejected rod worth is equal to or greater than $1. Should the core still be at a significant power level after the prompt critical power spike (such as for cases that do not trip), the DNB failure criterion as the high cladding temperature failure threshold should be used. The high temperature failure limit based on DNB should be applied to any other RIA transients that are not characterized by the prompt critical power spike. It is more appropriate that the switch between the PCMI limit and the high temperature failure limit based on whether the ejected rod worth will cause a prompt critical power spike. The PCMI criterion is applicable to a prompt critical case initiated at a power level greater than 5%. Likewise, the DNB criterion is applicable to a non-prompt critical case initiated at a power level below 5%.

It is conservative to continue to use the existing DNB correlations developed from steady state test data for RIA high temperature cladding failure evaluation of the PWR RIA cases. The following table illustrates the proposal for the clad failure limits with respect to initiating power level and ejected rod worth.

Table 1 Proposed Application of High Temperature Failure Criteria

	Ejected rod worth	
	≥$1 (prompt)	<$1 (non-prompt)
Initiating power level, %RTP	Failure criterion	
≥5	PCMI	DNB
<5	PCMI	DNB

Table 1 shows that there is a failure criterion for all power levels and all ejected rod worths.

4. Westinghouse Comment on NRC response [8]:

Westinghouse's previous comment on an earlier version of DG-1327 was that "There is no evidence of any fuel rod cladding failure due solely to the local heat flux exceeding the thermal design limit (e.g., departure from nucleate boiling and critical power ratios) for a prompt critical reactivity insertion." In response to the comment [8], the NRC made the following response: "The NRC disagrees with this comment. High temperature cladding failures were observed at several prompt test programs. This is the bases of the cladding failure thresholds in Section 3.1. The NRC staff acknowledges that time-in-DNB (or boiling transition) is necessary for cladding failure and that prompt critical accidents will likely only momentarily experience DNB conditions. In response to a different comment, the staff has added guidance allowing an alternative failure threshold." Westinghouse would like to clarify that within one second from the time of the peak power occurrence for a prompt critical reactivity insertion, there is no evidence of any fuel rod cladding failure due solely to the local heat flux exceeding the thermal design limit (e.g., departure from nucleate boiling and critical power ratios).

Additional Westinghouse comment on NRC response: In the NUREG/CR-0269 report in Section 3.1, Failure Modes:

> "No apparent damage occurred to rods for energy depositions up to about 120 cal/g UO_2. For energy depositions greater than about 120 cal/g UO_2, DNB occurred at the cladding surface. DNB resulted in oxidation of the cladding surface, the extent of which increased with increasing energy depositions. The first evidence of cladding failure, termed incipient failure, generally occurred at about 240 cal/g UO_2." [7 – pg. 57]

From this statement it can be concluded that in the range from 120 cal/g to 240 cal/g energy deposition, DNB occurs but the cladding damage is not sufficient to result in cladding failure in a short transient period. For prompt critical events, the proposed DG-1327 limits for PCMI conservatively envelope time at temperature failure from DNB. Westinghouse proposes for non-prompt critical RIA at part power operation, specific time at temperature cladding limits can conservatively be applied to calculated cladding time and temperature in DNB and separate failure from non-failure. For prompt critical cases that do not fail due to PCMI and remain at a significant power level (such as cases that do not trip), the DNB criterion will be applied following the prompt critical power excursion.

Additionally, the criteria that DNB results in cladding failure is excessively pessimistic. A review of the references that formed the original basis for short term high temperature limits [5] identified the various failure modes during or following high temperature oxidation and also defined a survivor's zone in terms of time at temperature that is well within the expected duration of an RIA at power.

A review of data from accident simulation tests using **ZIRLO** and **Optimized ZIRLO** cladding along with Zircaloy-4 and Zircaloy-2 cladding that show similar behavior in terms of oxidation rate, the formation of an oxygen stabilized alpha layer, and the ductile to brittle (DBT) transition at a range of temperatures. This data demonstrates that time and temperature limits applicable to Zircaloy-4 and Zircaloy-2 cladding are also applicable to **ZIRLO** and **Optimized ZIRLO** cladding.

In addition, the IFA-613 dry out tests [6] in Halden demonstrated the capability of a fuel rod to go through a short term high temperature experience and then operate following that event without failure and with adequate cladding mechanical properties. The duration of the IFA-613 tests was longer than the time frame for a DNB due to an RIA.

This provision should be made for time and temperature limits to evaluate cladding failure in an RIA under non-prompt conditions.

5. Comments on Fission Product Release Fractions Documented in Appendix B [1]:

Westinghouse has the following question and comments on the cited text:

a) In the first paragraph of page B-1 in the "Steady-State Fission Product Gap Inventory" section it states that, "The gap fractions from Table B-1 are used in conjunction with the calculated fission product inventory calculated with the maximum core radial peaking factor."

   Comment:
   This is a simple but conservative assumption. The guidance requiring the use of the maximum radial power factor should be revised to allow an alternative (more realistic but still conservative) calculation using actual power history.

b) Page B-1, Paragraph 2 states that, "For fuel that melts, the combined fission product inventory (steady-state gap plus transient release) is added to the release resulting from fuel melting. RG 1.183 (Ref. B-1) and 1.195 (Ref. B-2) provide additional guidance on fuel melt source term."

   Comment:
   Both cited regulatory guides have Appendix H for rod ejection defining 100% noble gas and 25% for iodine for containment leakage and 50% for iodine for secondary releases. But there is no guidance there relating to melt for Alkali metals. The NRC should provide guidance for alkali metals' fission product inventories.

c) The gas release calculation only supports fuel rod average burnup of 65 GWd/MTU (third paragraph on page B-1, and Figure B-1 on page B-2).

   Comment:
   This should be extended to support the industry efforts to go to higher allowable burnups. It is recommended that the figure support burnup to at least 68 GWd/MTU which industry seeks to achieve in the near-term. However, it would be ideal for the figure to support burnup to 75 GWd/MTU which the industry seeks to achieve in the next 5 to 7 years. The new ANS5.4 standard is based on database above rod average burnup of 70 GWd/MTU [9-page 4.10].

d) Item B-5 on page B-7 states that, "Rod power histories used in the fuel rod design analysis based on core operating limits report thermal-mechanical operating limits or radial falloff curves should be used."

Comment:
This text should be deleted as it is just one way to bound anticipated operation. The rest of the texts provides sufficient guidance for using conservative rod power histories.

e) On Page B-7 it states, “This example illustrates the potential improvement in the radiological source term from calculating less bounding gap fractions. For this example, the licensee elects to calculate gap inventories based on”. However, the text does not pick up on the next page.

Comment:
There are issues with the break between page B-7 and page B-8. It seems that some text may be missing from page B-8. Please correct the page break.

f) The table on Page B-10 has all the gap fractions set to the maximum value.

Comment:
This is too conservative for short life isotopes. Burnup dependent gap fractions (similar to power fall-off) are more appropriate.

REFERENCES:

1. US NRC, Draft Regulatory Guide DG-1327, “PRESSURIZED-WATER REACTOR CONTROL ROD EJECTION AND BOILING-WATER REACTOR CONTROL ROD DROP ACCIDENTS,” ML18302A106.
2. Westinghouse, WCAP-12610-P-A & CENPD-404-P-A, Addendum 1-A, “Optimized ZIRLO™.”
3. Westinghouse, WCAP-17642-P-A, Revision 1, “Westinghouse Performance Analysis and Design Model (PAD5).”
4. STP 1543, Robert Comstock and Pierre Barberis, Eds., doi: 10.520/STP1543201300058, ASTM International, (2014) as cited in Pan, G., Garde, A. M., Atwood, A. R., “Performance and Property Evaluation of High-Burnup Optimized ZIRLO Cladding,” *17th International Symposium on Zirconium in the Nuclear Industry*, February 3-7, 2013, Hyderabad, India.
5. Van Houten, R., NUREG-0562, “FUEL ROD FAILURE AS A CONSEQUENCE OF DEPARTURE FROM NUCLEATE BOILING OR DRYOUT.”
6. M.A. McGrath, et-al., “Investigation of the Impact of In-Reactor Short-Term Dry-Out Incidents on Fresh and Pre-Irradiated Fuel Cladding,” NUREG/CP-0180, pp 191-208, “Proceedings of the 2002 Nuclear Safety Research Conference,” Washington, DC.
7. Fujishiro T., Johnson R.L., MacDonald P.E., McCardell R.K., NUREG/CR-0269, TREE-1237, “LIGHT WATER REACTOR FUEL RESPONSE DURING REACTIVITY INITIATED ACCIDENT EXPERIMENTS.”
8. Response to Public Comments Draft Regulatory Guide (DG)-1327 (NRC Docket-2016-0233, ML18302A107.
9. J.A. Turnbull, C.E. Beyer, NUREG/CR-7003/PNNL-18490, “BACKGROUND AND DERIVATION OF ANS-5.4 STANDARD FISSION PRODUCT RELEASE MODEL.”